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Heat flow and heat production studies in North Dakota

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HEAT FLOW AND HEAT PRODUCTION STUDIES IN NORTH DAKOTA

by

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This dissertation submitted by Richard Scattolini in partial fulfillment of the requirements for the Degree of Doctor of Philosophy from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

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Title HEAT FLOW AND HEAT PRODUCTION STUDIES IN NORTH DAKOTA

Department Geology

Degree Doctor of Philosophy

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ABSTRACT

Thirty-one new heat flow determinations in North Dakota range from 0.6 to 1.9 HFU. The majority of heat flow measurements were completed for southwestern North Dakota.

Heat flow measurements were made in both oil and water wells. Heat production data from basement rocks when used in conjunction with nearby heat flow values indicate that only two of six sites may be considered to be similar to Basin and Range type of heat flow. One site occurs in southwestern North Dakota in a region west of 103° W where no heat flow value is less than 1.5 HFU. The other site is in north-central North Dakota and a Basin and Range interpretation for it seems to conflict with nearby heat flow data and is inconsistent with other available geophysical information.

The major conclusion is that a heat flow province transition between Basin and Range and eastern United States types of heat flow occurs west of 103° W longitude in southwestern North Dakota. There is coincidence between the heat flow results reported here and a zone of anomalous electrical conductivity reported by Alabi, Camfield and Gough (1975), although the transition is better delineated by the heat flow data. The width of the transition zone between heat flow provinces is narrow (28 km) implying a shallow depth to partially molten lower crust or upper mantle. When used with experimental petrologic data for peridotite in the presence of excess water, temperature calculations suggest

that a partial melt zone begins approximately at the depth of the Moho (45 to 55 km) as determined by seismic refraction data.

INTRODUCTION

Heat continually escapes the surface of the earth from its interior. The earth's heat flow generally occurs at quite low levels, so the heat flow is almost unrecognizable near the earth's surface because of incoming solar radiation. Exceptions occur near active volcanoes, geysers, fumaroles and hot springs where terrestrial heat flow is significantly greater.

When the earth's heat is recoverable, as with other forms of energy, it can be made to do useful work. The uses depend on the quantity of the heat present, the physical state of the matter containing the heat and the chemistry of the medium transporting the heat. In the earth, the "medium" is usually water or brine. Regions of geyser activity are proving to be of interest for the commercial generation of electricity. Regions of lesser heat content, containing transferrable quantities of fluid from porous and permeable rocks, may be used for space or process heating. It is the latter type of resource which may prove to be of interest in North Dakota.

Most of the heat flow in the crust of the earth occurs by conduction. However, sedimentary basins can be included as part of a resource base if aquifer systems exist which have adequate permeability to allow extraction of significant quantities of water. The term resource base means the reservoir of stored heat at temperatures greater than 15°C. Water of modest temperature for direct heating can be recovered from aquifers with appropriate permeability. Basins of normal heat flow containing such aquifer systems, may provide warm water but the temperatures would not increase rapidly with depth unless conductivities are low, providing a thermal blanket (Nathenson and Muffler, 1975).

The purpose of this study was to determine the terrestrial heat flow in the Williston basin of North Dakota. From a scientific standpoint, the thermal character of the crust of the earth under North Dakota can be better understood by a study of the heat flow.

Data was obtained from two types of wells. First, most of the heat flow values are based on temperatures measured in water wells of the United States Geological Survey's (USGS) observation water well network. These wells are used for water quality testing purposes and terminate in an aquifer. Wells greater than 150 m deep were employed where available. Those shallower than 150 m are primarily in eastern North Dakota and were the deepest available at the time for the areas studied. The remainder of the heat flow values are from temperatures measured in oil wells or wells drilled for that purpose.

PREVIOUS WORK

Little work on heat flow has been done in North Dakota. The first attempt at estimating heat flow in North Dakota was made by Blackwell (1969). Using temperatures originally reported by Van Orstrand in 1934, and by identifying the rock types penetrated by the borehole, Blackwell estimated the thermal conductivity as 3.5×10^{-3} cal / cm sec °C and estimated a heat flow for A. F. Blum # 1 near Lonetree, North Dakota as greater than 1.4 HFU. A heat flow unit or HFU is equal to 10^{-6} cal / cm^2 sec. These are the units used for heat flow throughout this report.

Combs and Simmons (1973) published two estimates of heat flow based on temperatures which Combs measured. The heat flow values were estimates because no core samples were available (Combs, 1970). An estimated thermal conductivity of 4.0×10^{-3} cal / cm^2 sec was used for the Pierre shale which led to estimates of 2.2 HFU for wells in Burke and Bottineau counties.

Scattolini and Howell (1973) reported heat flow values from one oil well in Billings county and repeated the heat flow calculations on two wells using temperatures reported by Combs and Simmons (1973) and measured thermal conductivities uncorrected for in situ porosity. These heat flow values will be discussed later in this report.

Temperature information is also available through the North Dakota Geological Survey (NDGS) as both bottom-hole temperatures and temperature-depth logs. Most of this information has been strongly affected by the drilling process and was collected by the oil industry for the purpose of determining the level reached by the cement in the casing-borehole annulus after the casing was emplaced. The details of drilling cessation, drilling period and actual drilling time are unavailable. Because of these factors, this data provides upper and lower bounds on the heat flow value but cannot be used to calculate a precise value of the heat flow.

OBSERVATIONAL METHODS

Introduction

The heat flow is determined by the site-specific thermal gradient and thermal conductivity of the earth. In order to determine the heat flow, measurements are made of thermal gradients and of thermal conductivities for rocks at depths of tens to thousands of meters. In the following section, the experimental techniques employed in measuring temperature to determine thermal gradient and in measuring thermal conductivity are discussed.

Two requirements for heat flow determination are: an opening in the earth and samples from that opening. The opening in the earth is generally a well in which temperature is measured as a function of depth. All temperatures reported here were obtained from oil or water wells or wells which were drilled for either purpose. All wells examined in this study were cased with either iron or plastic pipe. Since the NDGS maintains a sample library, drilled fragments (cuttings) were available for most of the wells examined in this study.

The results from two deep wells are included here. Both had been drilled by the oil industry and neither produced oil. NDGS 5086 was completed and pumped for two months but 95 percent of the production was water and production was discontinued. Barnwell Oil Ltd. permitted temperature measurements while it evaluated perforating NDGS 5086 at a different depth. NDGS 2894 was cased but never completed as an oil well. The United States government had used the well as part of an extended large amplitude seismic array (LASA). The seismometer had been removed at least one year before temperature measurements were made at this site.

In all but five wells, the values of heat flow reported here are based on data obtained from wells that had remained undisturbed for at least one year before temperature measurements were made (see Appendix A). This is sufficient time to allow the effects of drilling disturbances to subside. The measured temperature may not be the undisturbed terrestrial temperature but the thermal gradient is likely to have been reestablished (Lachenbruch and Brewer, 1959; Jaeger, 1961).

Five values of heat flow reported here are estimates made from industry temperature surveys from the NDGS well log files. NDGS 35, 424, 591, 1099, and 1139 are five of sixty oil industry thermal surveys selected because of their relative quality and their proximity to heat production data. The temperature data for NDGS 3342 and 3479 are from Combs and Simmons (1973) based on the dissertation of Combs (1970).

The remaining wells (29) are water observation wells maintained by the USGS Water Resources Branch. These wells were drilled as part of a cooperative program between the North Dakota State Water Commission (NDSWC), the County where the well is located and the USGS. Several of the sites used for this study are located in southwestern North Dakota. These wells were used for water quality studies and, except for limited quantities of water removed for chemical analysis less than four times per year, were undisturbed.

Since the annual surface temperature wave is known to affect depths to 20 m (Carslaw and Jaeger, 1959) deeper wells were chosen. The requirement is a minimum because as pointed out by Jaeger (1965) even wells less than 150 m deep are generally not used because of weathering or hydrologic uncertainties. In eastern North Dakota the latter requirement was relaxed to make use of the deepest wells available nearby to sites where basement rock samples of good quality and quantity were available. The use of these wells was justified simply because no heat flow data from these areas would be available without them.

The remainder of this section is devoted to a description of the temperature and thermal conductivity measurements and the calibration of the instrumentation used.

Temperature Measurements

The temperature measuring system consisted of a Fenwall Electronic thermistor probe sensor (bayonet type) electrically connected by four conductor cable to the surface, a hoist arrangement and a resistance measuring device. Two modes of operation were used.

1. The deep well mode was a trailer-mounted, electrically powered winch, with approximately 2 km of 0.4 cm (3/16 in.) steel armored electrically shielded, four-conductor logging cable which was assembled by Logmaster Corp. of Enid, Oklahoma. This mode was used in the two deep wells (NDGS 2894, 5086). For this mode, depth measurements were determined to an absolute precision of ± 0.03 m.

2. The second mode is a relatively portable winch with slightly less than 0.5 km of four conductor lightweight cable (Berktek Corp.

Reading, Pa.) with a second Fenwall thermistor probe used only for this mode. Most of the shallow well measurements were made with this apparatus which was constructed in the Physics Department at the University of North Dakota. For this mode, depth measurements were determined to an absolute precision of ± 0.15 m.

The primary method of resistance measurement at the surface employed a four lead resistance measurement using a Data Precision digital multimeter, model 2540 A2. In two instances, a back - up unit which consisted of a Siemens variant of the wheatstone bridge was used (see Sass and others, 1971c; Roy, Decker, Blackwell and Birch, 1968). Both systems compensate for the series resistance of the cable conductors.

At the site, the probe was lowered to a depth and allowed at least one hundred times the time constant of the probe (2 sec) to stabilize. This gave a measure of the uncertainty in the temperature for regions over which the heat flow was calculated (± 0.01 °C). Temperature measurements were made while logging into the well.

In the laboratory, both thermistor probes were calibrated against a Leeds and Northrup platinum resistance thermometer. The platinum resistance thermometer was standardized by Leeds and Northrup Inc. in 1975 against a standard traceable to the National Bureau of Standards.

The calibration process involved placing the thermistor probe and the platinum resistance thermometer in drilled holes in a solid cylinder of brass with large thermal inertia. The drilled holes were filled with fluid to insure good contact between the sensor and brass.

The brass cylinder, 7.62 cm in diameter and insulated with styrofoam at the top, was immersed in a Neslab Instruments constant temperature bath. The resistance of the thermistor was monitored using the digital multimeter; the resistance of the platinum resistance thermometer was monitored with a Honeywell potentiometer, model 2780. Measurements were made approximately every five degrees from 0 to 30 °C for the portable mode thermistor probe and from 0 to 100 °C for the trailer mounted mode thermistor probe. The voltage drop across a standard resistance in series with the platinum resistance thermometer was monitored to determine the current through the circuit followed by a measurement of the corresponding voltage drop across the platinum resistance thermometer. Repeated measurements at the same temperature with current reversal yielded agreement to better than ± 0.02 °C which imposes a limit of ± 0.02 °C on the absolute precision of the temperature measurements.

The thermistor calibration curve was produced by exponential curve fitting over five degree intervals using the exponential and pre-exponential as variables and calculating the mismatch for the five degrees above and below the fitted interval. The mismatch at the five degree step above and below the interval did not exceed ± 0.01 °C and on the five degree interval employed was less than ± 0.01 °C. Based on these considerations the maximum estimated error in temperature measurement was taken to be ± 0.03 °C.

Temperature comparisons between results obtained with these downhole temperature measurement systems and measurements made by two other investigators, Dr. E. R. Decker (University of Wyoming) and Dr. A. Jessop (Department of Mines and Mineral Resources, Canada), give reasonable thermal gradient agreement (see Table 1), indicating an error consistent with that estimated above.

TABLE 1

TEMPERATURE AND THERMAL GRADIENT COMPARISONS WITH OTHER INVESTIGATORS

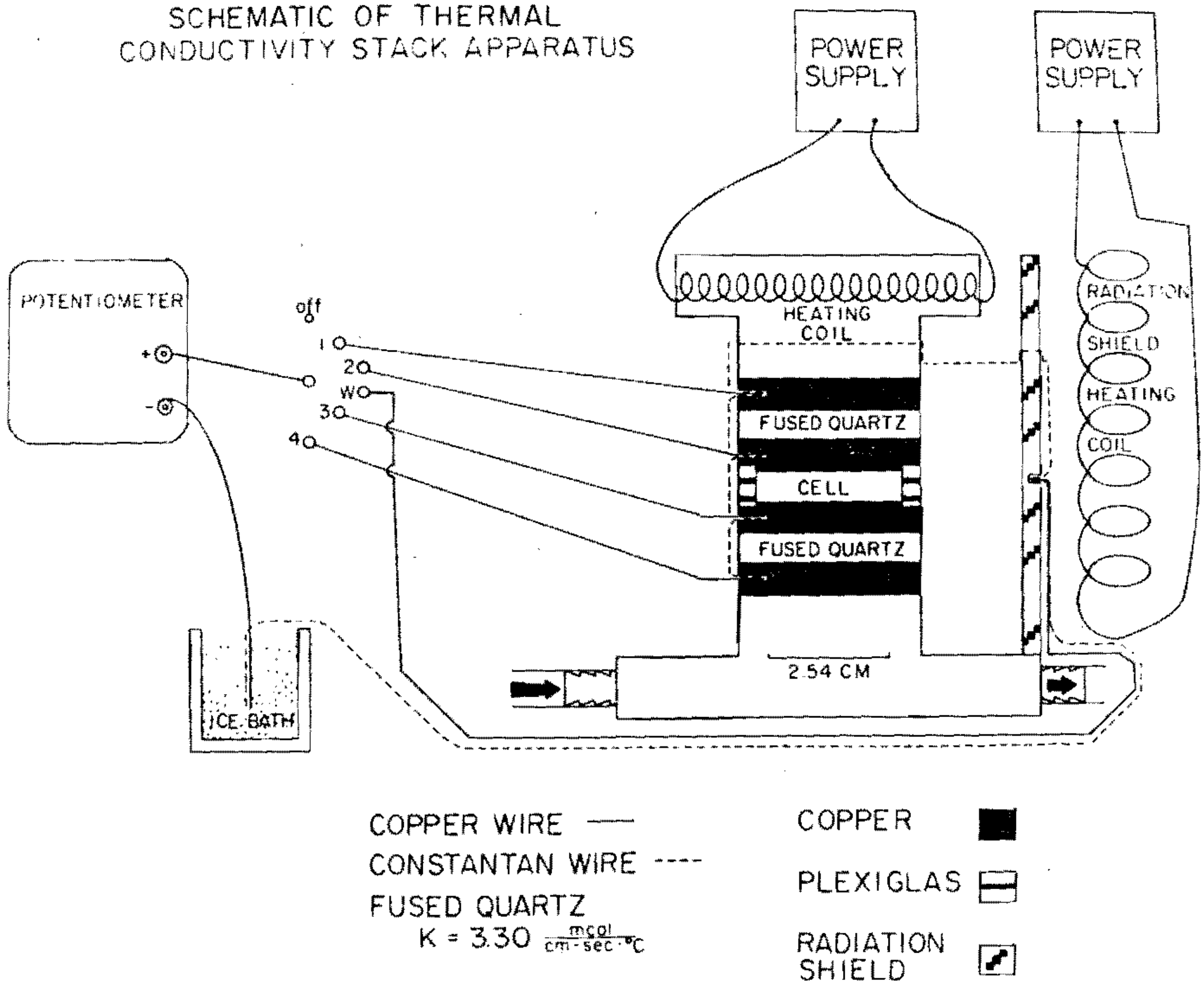
Depth Meters	Temperature °C	Thermal Gradient	Depth Meters	Temperature °C	Thermal Gradient
		University of Manitoba Well Site			
This report	July 5, 1975		Dr. A. Jessop	August 22, 1967	
228.6	8.41	10.26	221.3	8.3	10.73
454.76	10.73		458.1	10.84	
		NDGS 5086 Western North Dakota Well Site			
This report	July 14, 1975		Dr. E. R. Decker	March 10, 1974	
182.94	14.90	39.33	182.88	15.33	40.07
365.76	22.09		365.76	22.66	

Thermal Conductivity Measurements

Thermal conductivity measurements were made using a modified divided bar apparatus or stack (Birch, 1950). A nichrome wire heater maintained a constant elevated temperature at the top of this stack and fluid circulated from a constant temperature bath maintained the temperature of the cooler lower part of the stack (Figure 1). Radial heat loss was minimized by either using a radiation wall which was maintained at a constant temperature close to the temperature of the unknown sample or careful insulation with styrofoam. To reduce contact resistance copper disks were machined flat and polished. A

Fig. 1. Schematic of Thermal Conductivity Stack Apparatus. This is a modified divided bar similar to that of Birch (1950). The radiation shield was used initially but was later replaced by styrofoam. The cell contains rock fragments saturated with water. Arrows at the base of the divided bar indicate the flow direction to and from the constant temperature bath (not shown here) used as a heat sink. The reference thermocouple junction was placed in either the ice bath or the constant temperature bath and the appropriate correction applied to the voltage before temperature was calculated.

SCHEMATIC OF THERMAL
CONDUCTIVITY STACK APPARATUS



coating of household liquid detergent with a relatively high thermal conductivity and a load of 10 kilograms was used to reduce contact resistance. Stack temperatures were measured using copper-constantan junctions. Thermocouple voltage was measured by a Rubicon potentiometer. The potentiometer determined voltage to 0.001 mv which provides for a precision on the order of 0.01 °C. Divided bar reference conductors were highly polished disks of fused quartz.

The thermal conductivity of rock fragments was measured using the technique of Sass, Lachenbruch and Monroe (1971) because the available samples were drill cuttings. This method employs a cylindrical cell constructed of copper disks and a plastic retainer containing rock cuttings which is flooded under moderate vacuum with water. This cell with contents is placed in the stack between reference disks of fused quartz. The stack is then allowed to acquire thermal steady state. The unknown thermal conductivity of cell and included contents, the effective thermal conductivity, is computed from the ratios of the temperature drops across the thicknesses of the sample and references. This is all that is required to determine the unknown thermal conductivity of a cylindrical rock specimen. The thermal conductivity of the fragmented dry rock material inside the cell can be calculated from the following equation (Sass and others, 1971b).

$$K_r = K_w \left\{ \frac{D^2}{d^2} \frac{K_c}{K_w} - \frac{D^2-d^2}{d^2} \frac{K_p}{K_w} \right\}^{(1/1-\phi)} \qquad (1)$$

where K_r is the thermal conductivity of the dry rock.

D is the outside diameter of the cell.

d is the inside diameter of the cell.

K_w is the conductivity of water.

K_p is the conductivity of the plastic guard ring. The effect of the material in this cell wall is less than 5 percent.

ϕ is the volume fraction of water in the cell.

K_c is the effective thermal conductivity of the cell and its included contents.

Sediments and sedimentary rocks are not dry in situ so the value of K_r calculated from equation 1 is adjusted to give an in situ thermal conductivity based on the following equation (Sass and others, 1971b).

$$K_{pr} = K_w \left\{ \frac{D^2 K_c}{d^2 K_w} - \frac{D^2 - d^2}{d^2} \frac{K_p}{K_w} \right\}^{(1-\phi_o/1-\phi)} \qquad (2)$$

has all the same parameters as those previously defined with two exceptions.

K_{pr} is the thermal conductivity of porous rocks with space filled with water.

ϕ_o is an independent in situ porosity value. According to Sass and others (1971b), the general accuracy of this technique is ± 10 percent.

Laboratory measurements of porosity on core from the wells studied were not available, so the approach taken was to use geophysical well logs. Sonic or Density, the so-called absolute or total porosity logs were used where available. These measures of porosity are based on the assumption that only rock and water are present. In both of the following equations, 100 (ϕ_o) is the percentage of water in situ. For the density log data the following equation is used:

$$\phi_o = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_{liq}} \tag{3}$$

where ρ_{ma} is the matrix density.

ρ_b is the measured density on the log.

ρ_{liq} is the density of the liquid.

For sonic log data the following equation is used:

$$\phi_o = \frac{\Delta T - \Delta T_{ma}}{\Delta T_{fl} - \Delta T_{ma}} \tag{4}$$

Where ΔT is the measured transit time from the log.

ΔT_{ma} is the transit time in the rock matrix.

ΔT_{fl} is the transit time in the pore fluid.

(See Schlumberger, 1972).

The thermal conductivity apparatus was operated between 20 and 30 °C and no corrections for in situ temperature were made for samples from region of a well with temperatures less than 30 °C. Using the coefficients of Birch and Clark (1940), corrections to the thermal conductivities were made when the in situ temperature exceeded 30 °C.

DATA REDUCTION AND CALCULATION OF HEAT FLOW

Heat flow is the product of measured and properly corrected thermal conductivity and thermal gradients computed from measured temperatures. Temperature-depth plots were examined for linear regions. Before thermal conductivity was measured, samples were examined to determine lithology and were selected at regular intervals from within the region of linear temperature variation. For wells less than 450 m deep, the lithology of the sediments within the linear region was primarily clay. In the two oil wells examined, thermal conductivity measurements were made on shales.

The product of the thermal conductivity and thermal gradient is the uncorrected heat flow, based on the assumption that all of the heat transfer is by one-dimensional steady state conduction. If this assumption were valid in all cases, the heat flow values could be considered representative of the regional heat flow (Sass and others, 1971c).

Two methods of computing the heat flow used here were: the interval method (Gough, 1963), and the resistance sum method. Both methods were reviewed by Hyndman and Sass (1966).

The interval method permits calculation of the heat flow at regular intervals from discrete measured temperatures. The following equation yields Q_z, the heat flow parallel to the well.

$$Q_z = \frac{1}{N} \sum_{i=1}^{N} \frac{\Delta T_i K_i}{\Delta Z_i} \tag{5}$$

K_i is the interval thermal conductivity.

$\Delta T_i/Z_i$ is the interval thermal gradient (rise in temperature divided by the depth increase).

N is the number of heat flow determinations.

The second method used (Appendix A and Table 2 refers to this method as method #2 flux) depends only on two measured temperatures, one at the bottom and one near the top of the hole. The temperatures were chosen so that the upper temperature was below the depth affected by the annual surface wave and so as to avoid known near surface aquifers or other surface disturbances. For the shallow wells, the lower temperature used in the calculation was chosen above the measured bottom-hole temperature because the well terminated in an aquifer. To calculate the heat flow, Q_z, the following equation is used.

$$Q_z = \frac{\sum_{i=1}^{N} \Delta T_i}{\frac{1}{N} \sum_{i=1}^{N} R_i \Delta Z_i} \qquad (6)$$

where $R_i = 1/K_i$ and ΔZ_i is the thickness of the section of thermal conductivity K_i. The thermal resistance over the length of the borehole is then $\sum_i R_i \Delta Z_i$ (Hyndman and Sass, 1966).

Because of the difficulty in obtaining thermal conductivities representative of the entire stratigraphic section between the upper and lower temperatures, this method is less reliable than the interval method. When for a given heat flow study site it was found that the results of method 1 agreed with the results of method 2 to within 10 percent, it was interpreted as an indication of the reliability of the heat flow determined at that site.

Several factors could contribute to inconsistency in heat flow determinations. In the detailed analysis of heat flow on a single borehole, Beck and Judge (1969) showed that heat flow values based on 30 to 100 m sections of the borehole may differ from the mean value of heat flow by ± 20 percent. Several possible explanations were advanced. Among these were: underground waterflow, climatic changes, chemical reactions of geologic processes, differences in heat generation between geologic units, and the presence of geologic structures which would distort the heat flow lines. In the Williston Basin, the presence of geologic structure which would cause significant distortion of the heat flow is less important than the other possibilities. Corrections for climatic changes have uncertainties as large as the correction itself (see Sass, Lachenbruch, and Jessop, 1971) and were not undertaken here for this reason. Location of underground waterflow can be identified using the available geophysical well logs and sample descriptions. Sands, and in southwestern North Dakota, lignites are known to be aquifers. Anomalous negative gradients may also be caused by zones of larger hole size where perhaps there was poor thermal contact of pipe and sediment leading to convective instability in that part of the well (see Diment, 1967 and Gretener, 1967). The procedure followed here with respect to the interval method calculation was to avoid temperature data which was badly distorted and to allow for such factors in the uncertainty surrounding any one heat flow value. These were judgmental decisions based upon lithologic knowledge from the samples, the sample descriptions made when the well was drilled and from the available geophysical well logs. Little work has been done on the problem of chemical reactions from the standpoint of temperature effects but in North Dakota oxidized zones should occur at depths less than 50 m. Little work has been done on the problem of heat generation within the sediments. One might expect that sands would differ from shales because of the well known adsorption properties of clays for large cations like potassium, for example. These problems are mentioned to indicate the uncertainty inherent in determining a heat flow value and the difficulty in determining the reliability of any one heat flow value.

The procedure followed here was to determine linear regions from a detailed plot of the temperatures. The interval method employed intervals of heat flow from within the linear region of temperature with a single interval outside this region as an additional check on the validity of the value obtained. For the deeper wells examined in this study, several linear regions were examined and interval calculations were based on thermal conductivity stratification which corresponded to major lithologic changes observed from well logs. In the water wells, a linear region was examined in detail and interval calculations done within the region of linear increase of temperature. Details of the interval calculation are presented for each temperature log in Appendix A. The calculation of the standard error is used as a formal estimate of the reliability of the heat flow value. This may not account for all sources of error but the heat flow values are probably accurate to within reasonable limits relative to the standard error.

Three broad categories have been used to account for the large range in the quality of the data. The criteria for the categories described are objective and where borderline cases occurred the heat flow value was lowered to a more uncertain category.

Category 1. Temperature profiles for this category are smooth and show no disturbances below near surface effects. These are determinations of the highest quality which have standard errors of less than 0.1.

Category 2. Standard errors for this category range from 0.1 to 0.2. Arbitrarily included here are heat flow values which showed category 1 standard errors but for which in situ porosity data was unavailable. Heat flow values with category 1 standard errors but with limited thermal conductivity data have also been included here. Also, judgmental assignments of data from wells less than 150 m deep have been included.

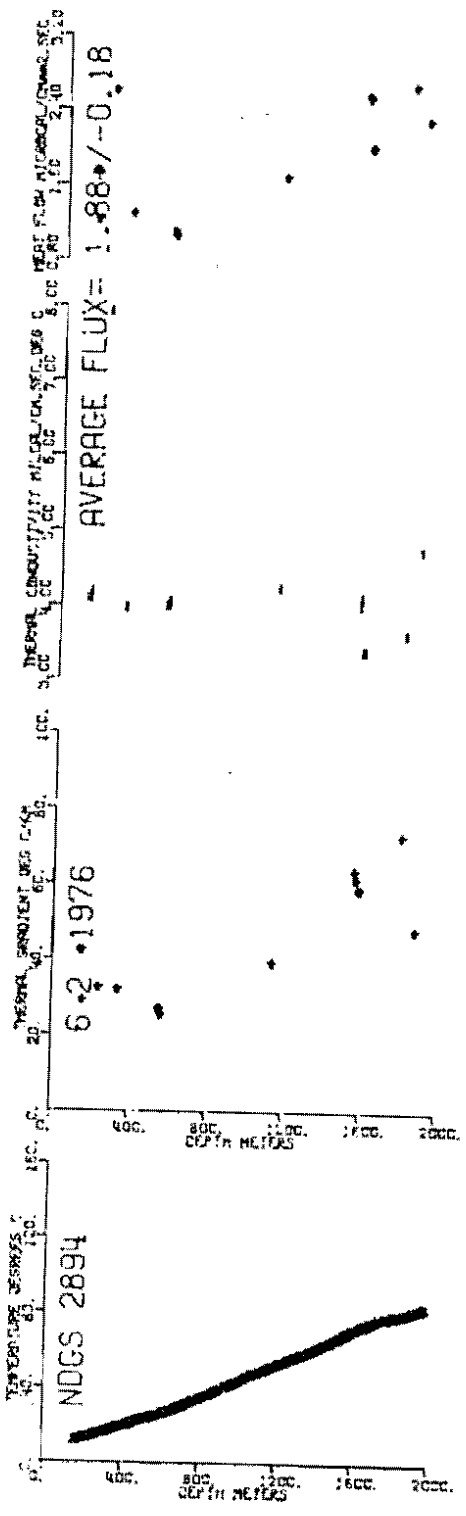
Category 3. These values of heat flow can be regarded as only rough estimates and have standard errors greater than 0.2. Heat flow values for most of the wells less than 150 m deep fall into this category.

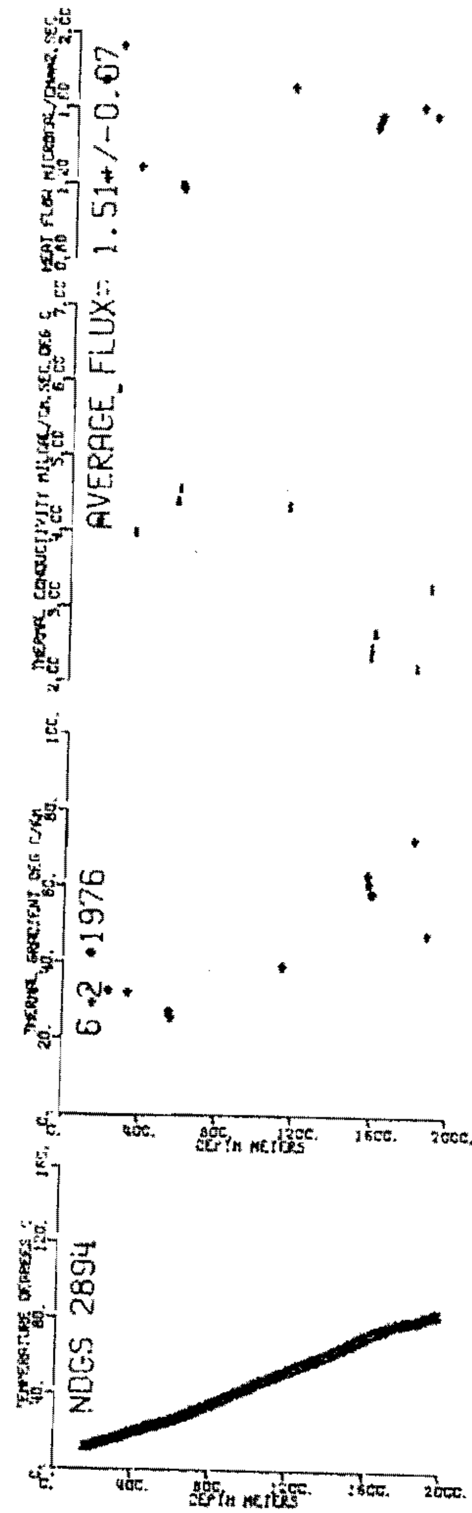
Internal consistency in the heat flow value is an indication of the reliability of the heat flow value. The assumption here is that climatic changes, chemical reactions, heat generation within the sediments, and underground water flows are limited in their vertical influence and magnitude and do not significantly alter the value of the conductive heat flow. The internal consistency as calculated by the standard error is taken to be a fundamental measure of reliability of the value obtained for the conductive heat flow. This internal consistency requires that thermal gradient and thermal conductivity change vertically in the borehole so that a uniform heat flow is observed. In ideal circumstances, this value of the heat flow would be a constant, so that when the value of the thermal gradient falls the value for the corresponding thermal conductivity would increase.

The data from well NDGS 2894 shows such internal consistency and is presented in Figure 2. In the upper set of plots, the thermal gradients and thermal conductivities seem to indicate such internal consistency but the standard error for the average flux calculated by the interval method is large (±0.18). Heat flux is heat flow per unit area and is in reality what has been referred to as heat flow in this report. After making corrections to the thermal conductivities for in situ porosity in the lower set of plots in Figure 2 the gradients and conductivities show internal consistency but the effect is much stronger. Note that the lower plot with corrected thermal conductivities gives a lower value of heat flow (1.51 HFU) and also a smaller standard error (±0.07).

The use of in situ porosity corrections appears justified from an examination of the scatter of the heat flow values and thermal conductivity. Figure 2 shows this data in a corrected and uncorrected case for well NDGS 2894. Similar reduction in scatter is observed for every well for which this information was available and as in NDGS 2894 the standard error is dramatically improved.

Fig. 2. Details of Heat Flow Calculation for Well NDGS 2894. Temperature, thermal gradient, thermal conductivity and heat flow are all plotted as a function of depth. The upper and lower plots of temperature against depth and thermal gradient against depth are identical. Thermal conductivities in the top set of graphs are uncorrected for porosity. The lower set of graphs contains thermal conductivity corrected using in situ porosity data obtained from a sonic log run when the well was drilled.


NDGS 2894
6-2-1976
AVERAGE FLUX= 1.88+/-0.18
DEPTH METERS


NDGS 2894
6-2-1976
AVERAGE FLUX= 1.51+/-0.07
DEPTH METERS

THE HEAT FLOW VALUES

The heat flow values are presented in Table 2. Wells with more than one temperature log are given one line for each temperature log in the table. Heat flow values which have been calculated from temperature measurements from other sources such as the five industry logs and the two wells of Combs and Simmons (1973) are recomputed here and only the recomputed value is listed in Table 2.

The well numbers of column 1 in Table 2 are those numbers given wells by the North Dakota Geological Survey (NDGS designated A in Table 2) and the North Dakota State Water Commission (NDSWC designated B in Table 2). Wells with the A designation are oil wells or were drilled for that purpose. Wells with the B designation are part of the Observation Water Well Network. All wells with B designation terminate in an aquifer.

The number in the next column labelled reference is keyed to the bottom of Table 2. These references are the NDSWC county basic data reports which contain sample descriptions, geophysical well logs and hydrologic data. Where no number is present, the basic data report has not at the time of this writing been published but the logs were available through the NDGS. Geophysical well logs for the oil wells are part of the NDGS well log files.

In Table 2, the location columns consist of latitude and longitude each listed in degrees to the nearest minute. Using this information, the wells were ordered from south to north. The next column lists the date the temperatures were measured in month, day and year order. The collar elevation is next followed by the depth to which temperature measurements were made. The average thermal gradient in °C/km which was used in the interval method calculations is followed by the average thermal conductivity in millical/cm sec °C. The next column is the depth range from which intervals were selected. In wells deeper than 150 m, most of the intervals selected were in the lower part of the depth range.

The next five columns are heat flow values. The first column is the heat flow value resulting from the interval method calculation. The next column is the results of the resistance sum method of calculating heat flow referred to here and in Appendix A as method #2. The next three columns show the category of the value of heat flow from the site rounded to the appropriate number of significant places after the decimal point. The next column is the statistical standard error of the heat flow. The standard error is equal to $\sigma/\sqrt{N}$ (Weinberg and Schumaker, 1962). The statistical standard deviation is σ and N is the number of intervals used from the number of heat flow intervals calculated.

Some lines in Table 2 show additional symbols beyond the standard error column which indicate additional pertinent information. The explanation for these symbols is at the bottom of the table.

The next to the last column gives the formation which provided the lithologic samples for thermal conductivity measurements. The abbreviated formation names are written out at the bottom of the table. The last column shows the dominant lithology encountered in the intervals used to calculate heat flow.

TABLE 2

HEAT FLOW IN NORTH DAKOTA

Well Number	Reference[a]	North Latitude Deg.	North Latitude Min.	West Longitude Deg.	West Longitude Min.	Date of Log Month	Day	Year	Collar Elevation m	Well Depth Logged m	Average Thermal Gradient °C/km	Average Thermal Conductivity mcal/cm sec °C	Depth Range Used for Method 1 m	Q, Uncorrected Heat Flow 10^{-6}cal/cm^{2}sec Method 1	Method 2	Heat Flow Categories 1	2	3	Standard Error[b]	Formations Dominating Thermal Conductivity Measurements[c]	Dominant Lithology of Samples Used for K
B 4501	1	46°	2	100°	7	7	26	1977	551.4	115.8	32.10	3.72	53-115	1.19	1.20		1.2		.11	G.D.	clay
B 4526	2	46°	9	101°	20	6	19	1976	730.0	250.2	30.23	4.17	45-230	1.23	1.17		1.2		.16	H.C.	clay
B 4526	2	46°	9	101°	20	10	5	1976	730.0	241.4	21.81	4.27	45-231	.93	1.07		1.0		.15	H.C.	clay
B 4462	3	46°	11	103°	29	8	15	1975	897.6	295.7	37.42	4.53	91-289	1.68	1.73	1.68			.06	H.C.	clay
B 4462	3	46°	11	103°	29	8	15	1975	897.6	194.8	41.62	4.54	91-183	1.87	2.05	1.87			.06+	H.C.	clay
B 8912	1	46°	14	100°	19	7	27	1977	510.3	102.4	35.34	3.90	53-100	1.29	1.09			1.2	.35	G.D.	clay
B 3627	4	46°	13	102°	4	7	26	1975	752.6	331.3	27.41	5.67	104-320	1.58	1.54		1.6		.18++	H.C.	silt
B 3164	5	46°	16	98°	57	7	4	1976	301.7	61.3	18.03	4.31	38- 53	.77	.74		.8		.05+,++	G.D., G.L.S.	clay
B 8117	1	46°	22	100°	30	7	27	1977	510.3	66.4	38.42	4.09	57- 64	1.52	1.50		1.5		.04+,++	G.D.	clay
B 4310		46°	24	103°	41	7	3	1976	396.2	396.5	35.21	4.40	76-365	1.54	1.61	1.54			.06	H.C.	clay
B 2180	5	46°	31	97°	12	7	4	1976	318.5	76.8	21.50	3.57	40- 67	.76	.74		.8		.07+,++	G.D., G.L.S.	clay
B 4509	2	46°	30	101°	58	3	31	1976	719.9	327.0	28.69	7.15	245-306	2.05	1.98		2.0		.10++	H.C.	sand
B 4509	2	46°	30	101°	58	6	19	1976	719.9	321.6	34.59	7.15	244-320	2.46	1.96			2.2	.22*,++	H.C.	sand
B 4811		46°	33	103°	17	3	27	1976	877.8	423.1	43.27	4.37	79-396	1.87	1.95		1.9		.15	H.C.	clay
B 4811		46°	33	103°	17	10	6	1976	877.8	454.2	33.90	4.37	76-396	1.45	1.95			1.7	.34*	H.C.	clay
B 4485	2	46°	40	101°	47	3	31	1976	643.1	281.0	26.64	3.53	61-168	.94	.91	.94			.06	L.C.	clay
B 4485	2	46°	40	101°	47	10	5	1976	643.1	286.5	57.03	3.53	61-168	2.05	1.84			1.9	.32*	L.C.	clay
B 4511	2	46°	42	101°	55	10	7	1976	702.6	315.8	34.89	3.60	46-122	1.21	1.30		1.2		.14	L.C.	clay
B 4511	2	46°	42	101°	55	3	31	1976	702.6	315.8	27.54	3.50	76-122	.95	.90		.9		.02+	L.C.	clay
B 3690	4	46°	45	103°	8	7	26	1975	798.6	232.6	39.19	3.02	122-168	1.18	1.09			1.1	.29+	H.C.	clay

TABLE 2--Continued

Well Number	Ref-er-ence[A]	North Latitude Deg.	North Latitude Min.	West Longitude Deg.	West Longitude Min.	Date of Log Month	Day	Year	Collar Eleva-tion m	Well Depth Logged m	Average Thermal Gradient °C/km	Average Thermal Conductivity mcal/cm sec °C	Depth Range Used for Method 1 m	Q, Uncorrected Heat Flow 10^{-6}cal/cm^{2}sec Method 1	Method 2	Heat Flow Categories 1	2	3	Standard Error[b]	Formations Dominating Thermal Conductivity Measurements[c]	Dominant Lithology of Samples Used for K
B 3433	6	47°	1	102°	8	7	25	1975	634.0	371.9	24.75	3.65	76-320	.90	.98	.90			.03	L.C., H.C.	clay
B 3433	6	47°	1	102°	8	3	30	1976	634.0	371.9	28.80	3.65	76-320	1.05	1.02		1.0		.11	L.C., H.C.	clay
B 4662	7	47°	2	102°	28	8	14	1975	657.8	240.8	26.96	4.30	76-137	1.16	1.13	1.16			.06	S.E.	clay
B 3558	6	47°	7	101°	16	5	14	1975	611.4	310.9	24.19	4.91	55-293	1.19	1.02		1.1		.16	L.C., H.C.	clay
B 3558	6	47°	7	101°	16	7	25	1975	611.4	304.8	25.26	4.91	61-289	1.26	1.03		1.1		.19	L.C. H.C.	clay
A 2894	11	47°	7	103°	40	6	2	1976	815.6	1981.2	44.48	4.36	137-1885	1.88	1.66		1.8		.18++	L.C., H.C., F.H., P., G., B.F., M., Mo., S.	shale
A 2894	11	47°	7	103°	40	6	2	1976	815.6	1981.2	44.48	3.71	137-1885	1.51	1.33	1.51			.07	L.C., H.C., F.H., P., G., B.F., M., Mo., S.	shale
A 2894	11	47°	7	103°	40	3	27	1976	815.6	453.2	31.50	4.53	122-336	1.43	1.46		1.4		.18+	L.C., H.C.	clay
B 4312		47°	10	104°	0	3	27	1976	726.9	292.6	36.75	4.39	152-243	1.62	1.62			1.6	.21++	H.C.	clay
B 4399	7	47°	19	102°	38	8	13	1975	692.8	293.8	30.62	3.54	76-274	1.08	1.13	1.08			.07	S.E., T.R., L.C.	clay
B 4814		47°	17	103°	18	3	25	1976	777.2	454.1	39.83	4.34	168-427	1.72	1.73	1.72			.06	T.R.	clay
B 4815		47°	17	103°	18	3	26	1976	777.2	442.0	39.64	4.34	168-427	1.71	1.65	1.71			.05*	T.R.	clay
B 4814		47°	17	103°	18	4	23	1976	777.2	503.0	38.63	4.31	162-427	1.65	1.82		1.7		.10*	T.R.	clay
B 4815		47°	17	103°	18	4	23	1976	777.2	471.7	35.97	4.34	162-427	1.55	1.82	1.55			.09	T.R.	clay
B 3991	8	47°	20	97°	32	2	22	1975	249.9	129.5	60.59	2.72	61-122	1.45	1.54			1.5	.30	G.D., N., G.	shale
B 3991	8	47°	20	97°	32	3	14	1975	249.9	131.1	58.40	2.72	58-122	1.34	1.34			1.3	.32	G.D., N., G.	shale
B 3991	8	47°	20	97°	32	7	27	1975	249.9	131.1	34.72	2.54	61-122	.95	1.10			1.0	.43*	G.D., N., G.	shale

TABLE 2--Continued

Well Number	Reference[a]	North Latitude Deg.	North Latitude Min.	West Longitude Deg.	West Longitude Min.	Date of Log Month	Day	Year	Collar Elevation m	Well Depth Logged m	Average Thermal Gradient °C/km	Average Thermal Conductivity mcal cm sec °C	Depth Range Used for Method 1 m	Q, Uncorrected Heat Flow 10^{-6}cal/cm^{2}sec Method 1	Method 2	Heat Flow Categories 1	2	3	Standard Error[b]	Formations Dominating Thermal Conductivity Measurements[c]	Dominant Lithology
B 3575	6	47°	27	102°	11	5	14	1975	646.4	236.2	28.53	3.36	76-213	.94	.94	.94			.03	S.B., T.R.	[illegible]
B 3575	6	47°	27	102°	11	4	22	1975	646.2	228.6	23.33	3.63	122-213	.81	.68			.7	.29*	S.B., [illegible]	[illegible]
B 4397	7	47°	28	102°	53	8	14	1975	771.4	170.7	37.04	3.35	61-167	1.23	1.30		1.3		.14	S.B.	Clay
A 5066	11	47°	28	103°	48	7	24	1976	722.1	1449.3	44.64	3.65	121-1449	1.62	1.61	1.62			.09**	B.C., F.H., P., K., G., S.F.	Shale
A 5086	11	47°	28	103°	48	7	14	1975	722.1	1950.8	43.10	3.36	142-1885	1.30	1.37		1.5		.085	B.C., F.H., P., K., G., S.F., Sh., Mo., S.	Shale
A 5086	11	47°	28	103°	48	7	13	1975	722.1	425.8	33.63	4.00	146-168	1.36	1.32			1.3	.20*	B.C.	Clay
B 2615	9	47°	47	97°	3	9	15	1976	259.1	68.0	20.60	3.17	30-61	.96	.55			.7	.30*,++	[illegible] L.S.	Clay
B 2615	9	47°	47	97°	3	9	15	1976	259.1	68.0	10.65	[illegible]	23-61	.51	.55			.5	.11++	[illegible]	[illegible]
B 2430	9	47°	57	97°	4	9	15	1976	251.8	64.0	13.39	4.52	23-53	.59	.57			.6	.09++	[illegible]	[illegible]
A 35	11	48°	17	102°	57	4	13	1932	705.9	2221.1	34.37	[illegible]		1.37	1.37			1.4	.5 **	[illegible]	
A 424	11	48°	19	102°	54	7	19	1954	721.3	2560.3	22.56	[illegible]		1.31	1.31			1.5	.5 **	[illegible]	
A 591	11	48°	13	102°	59	7	16	1954	633.4	1825.7	24.06	[illegible]		.96	.96			1.0	.5 **	[illegible]	
A 1009	11	48°	12	102°	57	4	8	1956	657.8	2221.7	27.34	4.00		1.09	1.09			1.1	.5 **	[illegible]	
B 3536	10	48°	36	97°	40	6	6	1975	278.4	104.2	20.74	[illegible]	55-82	.83	.83		.8		[illegible]	[illegible]	[illegible]
B 3830	10	48°	38	97°	40	2	21	1976	274.3	91.4	25.16	[illegible]	55-82	1.05	1.05			1.0	.44*,++	[illegible]	[illegible]
B 3827	10	48°	41	97°	52	7	1	1975	314.5	126.5	43.25	[illegible]	55-91	1.36	1.36		1.4		[illegible]*,++	[illegible]	[illegible]
B 3842	10	48°	46	97°	45	7	1	1975	307.2	95.4	19.65	4.00	64-82	.76	.98			.9	.22*,++	[illegible]	[illegible]
A 1139		43°	50	101°	2	6	8	1956	456.9	789.0	24.21	4.90		1.00	1.00			1.0	.5 **	[illegible]	

TABLE 2--Continued

Well Number	Reference[a]	North Latitude Deg.	North Latitude Min.	West Longitude Deg.	West Longitude Min.	Date of Log Month-Day-Year	Collar Elevation m	Well Depth Logged m	Average Thermal Gradient °C/km	Average Thermal Conductivity mcal/cm sec °C	Depth Range Used for Method 1 m	Q, Uncorrected Heat Flow 10^{-6}cal/cm^{2}sec Method 1	Q, Uncorrected Heat Flow 10^{-6}cal/cm^{2}sec Method 2	Heat Flow Categories 1	Heat Flow Categories 2	Heat Flow Categories 3	Standard Error[b]	Formations Dominating Thermal Conductivity Measurements[c]	Dominant Lithology of Samples Used for K
A 3479	12	48°	55	102°	26	9 13 1964	592.5	1500.0	47.02									P., N., [illegible], S.	
A 1280		48°	55	102°	26		592.5			3.73	832-1682	1.69	1.48		1.6		.11		shale
A 3342	12	48°	56	100°	40	9 12 1964	460.2	940.0	46.82									P., N., [illegible], S.	
A 2491		48°	56	100°	40		460.2			3.81	300-845	1.75	1.69		1.7		.10		shale

[a]1. Armstrong (1975)
2. Randich (1975)
3. Croft (1974)
4. Trapp, Jr. (1971)
5. Baker, Jr. (1966)
6. Croft (1970)
7. Klausing (1976)
8. Downey, Hutchinson and Sunderland (1973)
9. Kelly (1968
10. Hutchinson (1973)
11. Carlson and Anderson (1966)
12. Combs and Simmons (1973)

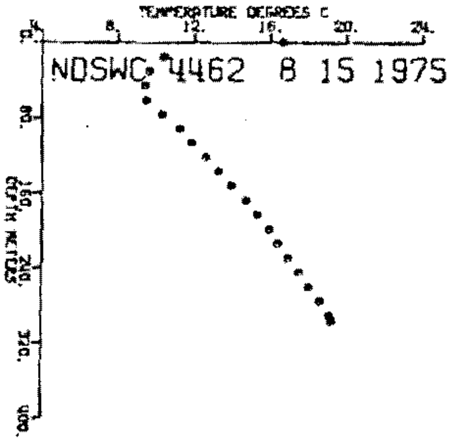
[b]+ Statistics probably invalid because too few thermal conductivities were measured.
* Temperature log shows evidence of thermal transient of unknown origin.
** Gradients probably too low because temperatures were measured too soon after drilling termination. Thermal conductivity is estimated. Standard Error is estimated.
++ No in situ porosity data was available.
§ Temperatures measured while well was venting a small amount of gas to the atmosphere and a small amount of fluid to the nearby mud pits.
§§ Temperatures measured by using a lubricator to maintain fluids in the well.

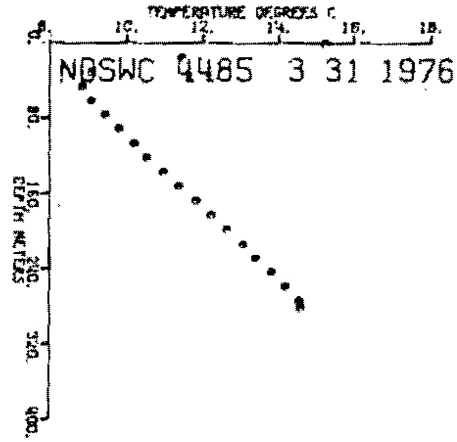
[c]G.L.S. = Glacial Lake Sediment;
G.D. = Glacial Drift,
S.B. = Sentinel Butte Formation;
T.R. = Tongue River Formation;
L.C. = Ludlow-Cannonball Formations (undifferentiated);
H.C. = Hell Creek Formation;
F.H. = Fox Hills Formation;
P. = Pierre Formation;
N. = Niobrara Formation;
G. = Greenhorn Formation;
B.F. = Belle Fourche Formation;
M. = Mowry Formation;
Mo. = Morrison Formation;
S. = Sundance Formation;
Pi. = Piper Formation.

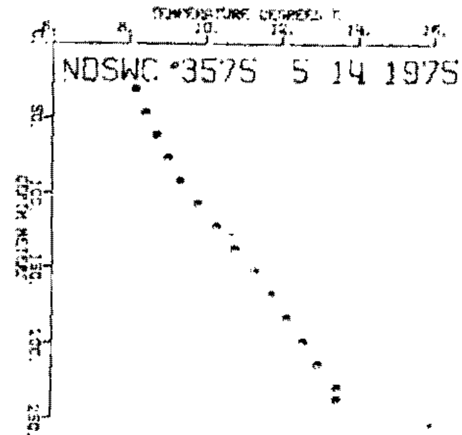
Several of the wells which yield category 1 heat flow results (Figure 3) show near surface disturbances to the temperatures in the uppermost part of the well. Two important observations need to be made with regard to temperatures shallower than 40 m. First the uncertainty in these temperatures is large (± 0.1°C). Second, none of the near surface temperatures were used in calculation of heat flow. In one case, NDSWC 3575, the presence of an abandoned one-room schoolhouse foundation adjacent to the well site may have caused the decrease in slope of the temperature depth curve. No formal corrections to the temperatures have been made because details of the history of the building are unknown. Such observations on heated buildings and basements are not new (see Roy and others, 1972; Lachenbruch, 1950).

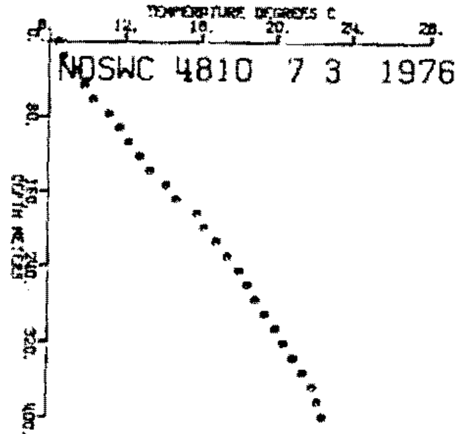
Fig. 3. Temperature - Depth Plots of Category 1 Type. Six of temperature depth plots which yield category 1 type of heat flow are shown here. The well number and date of log in month, day and year are shown for each plot.

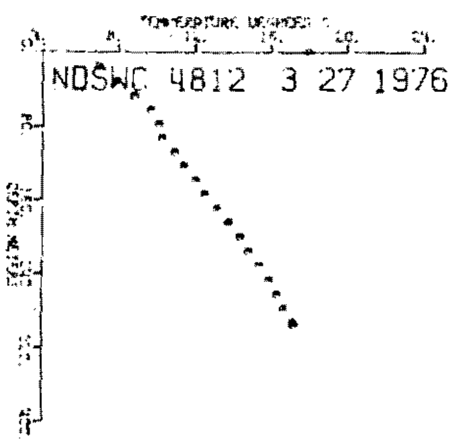
Three of these logs, NDSWC 4462, 4810 and 4812, all yield a higher than normal conductive heat flow. Note that both the temperature and depth scales vary between diagrams.

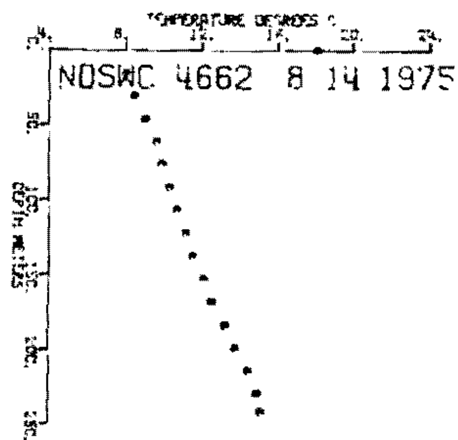

TEMPERATURE DEGREES C
4. 8. 12. 16. 20. 24.
NDSWC 4462 8 15 1975
DEPTH METERS
0. 80. 160. 240. 320. 400.


TEMPERATURE DEGREES C
8. 10. 12. 14. 16. 18.
NDSWC 4485 3 31 1976
DEPTH METERS
0. 80. 160. 240. 320. 400.


TEMPERATURE DEGREES C
6. 8. 10. 12. 14. 16.
NDSWC 3575 5 14 1975
DEPTH METERS
0. 50. 100. 150. 200. 250.


TEMPERATURE DEGREES C
8. 12. 16. 20. 24. 28.
NDSWC 4810 7 3 1976
DEPTH METERS
0. 80. 160. 240. 320. 400.


TEMPERATURE DEGREES C
4. 8. 12. 16. 20. 24.
NDSWC 4812 3 27 1976
DEPTH METERS


TEMPERATURE DEGREES C
4. 8. 12. 16. 20. 24.
NDSWC 4662 8 14 1975
DEPTH METERS
0. 50. 100. 150. 200. 250.

DISCUSSION OF THE HEAT FLOW VALUES

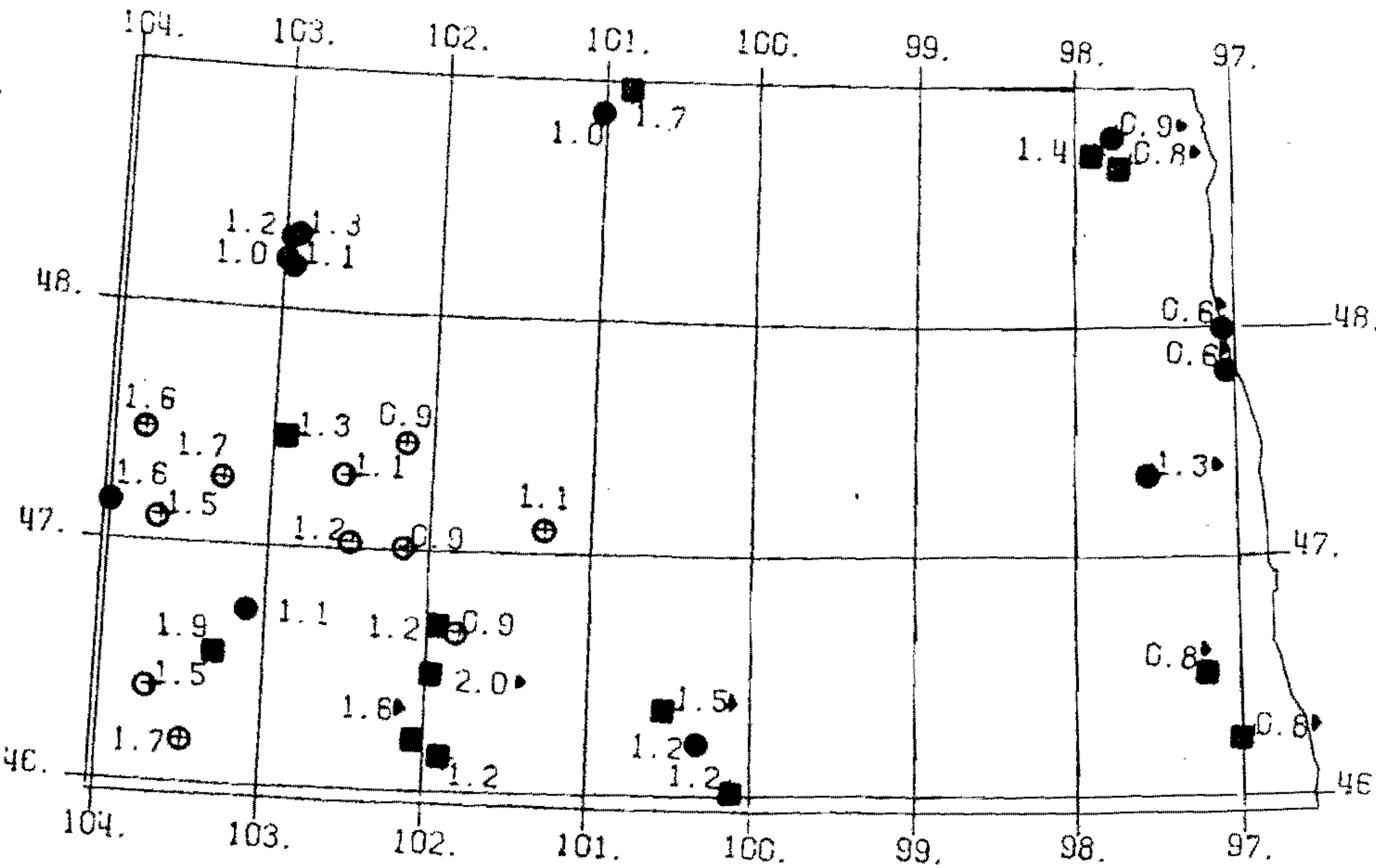
Table 2 contains fifty-seven heat flow determinations from thirty-six sites. Of these, fifty are new determinations from twenty-nine sites; five are determinations based on oil industry thermal surveys available from NDGS files for two locations. Two determinations are based on temperatures reported by Combs (1970) for two locations.

Each of the twenty-nine water wells employed in this study took from one day to two weeks to drill. The temperatures from this class of well were not measured sooner than one year after the drilling occurred (see Appendix A). Therefore, no corrections to the temperature for drilling disturbance were necessary. The near surface temperatures were not used in the calculation of heat flow. Wells labelled B are NDSWC wells of the observational water well network. Well locations are in Table 2 and, are also listed in Appendix A where a well location map (Figure 14) and the data on individual wells can be found. All references to temperature depth plots will be to Figures 3, 6 or to Appendix A.

The best value for the heat flow was selected for the map (Figure 4) from Table 2 on the basis of standard error. In a few instances where the standard error was large the results of method 1 and method 2 were averaged and that heat flow value was used for Figure 4.

Three wells in south central North Dakota B 4501, B 8912 (see Figure 6) and B 8117 give heat flow values of 1.2, 1.2 and 1.5 HFU

Fig. 4. Heat Flow Values in North Dakota. Numbers within the outline map of North Dakota are heat flow values in HFU rounded to one significant figure beyond the decimal point. Category 1 values are indicated by open circles with crosses in them. Category 2 values are solid squares. Category 3 values are solid circles. Triangles to the right of heat flow values indicate lack of independent in situ porosity data. All sites east of 101° W latitude are shallower than 135 m except the 1.7 HFU value in north central North Dakota which is 940 m.


104.
103.
102.
101.
100.
99.
98.
97.
48.
47.
46.
1.7
1.0
0.9
1.4
0.8
1.2
1.3
1.0
1.1
0.6
0.6
1.6
1.3
0.9
1.7
1.1
1.3
1.6
1.5
1.1
1.2
0.9
1.1
1.9
1.2
0.9
0.8
1.5
2.0
1.6
1.5
0.8
1.7
1.2
1.2
1.2

respectively. The thermal conductivities for B 8117 are uncorrected for porosity; the heat flow value is probably too large by approximately 30 percent, a common correction value for clay-rich materials. Notice in Table 2 that the two wells for which in situ porosity is available are roughly equivalent in heat flow even though B 4501 is less certain than B 8912. Since the uncertainty in B 8912 was so large, the results of both methods of computing heat flow were averaged and that value (1.2 HFU) was used at this site in south central North Dakota.

B 4526 was listed twice in Table 2 because temperatures were measured twice. The values of heat flow for both logs are in agreement within the uncertainty of ± 0.2 HFU. The heat flow chosen for Figure 4 is the 1.2 HFU value because of agreement between the two methods of calculating heat flow for the June 19, 1976 log.

B 4462 was listed twice in Table 2 because two of three wells at this site underwent temperature measurement. The two wells used were within 60 m of each other. The shallower well is north of the deeper well (see Figure 3 for deep well temperatures). The same thermal conductivities were used for both wells over the depths where applicable. The temperatures from approximately 60 to 194 m depth in the shallow well, agree closely with temperatures measured in the deeper well. If interval heat flow values for the same depths are compared, the agreement is within 5 percent. This suggests that the isothermal surfaces within the earth are continuous and parallel to the surface. The differences in temperature above 60 m depth would appear to be related to differences in well construction. The deeper well had a cemented surface casing while the shallow well merely had the iron pipe loosely set in the open hole which was water-filled to the surface when logged. Temperatures were logged after overnight rainfall.

A possible interpretation of the near surface temperature differences may be that a near surface aquifer, marked by the presence of a third and even shallower well (see Croft, 1974) than the two previously discussed, was accepting the temporary excess of fluid in the borehole. This would explain the temperature differences above and the temperature similarity below 60 meters. In calculating the conductive heat flow, the temperatures above 60 m were not used. There is detailed thermal conductivity data and good in situ porosity data to justify the higher than normal heat flow 1.68 ± 0.17 HFU and rounded off to 1.7 HFU in Figure 4.

Well B 3627 listed in Table 2 shows a near surface high temperature aberration which occurs in sand and is thought to be an aquifer. The heat flow was calculated below the temperature aberration. This site is one of three identified on Figure 4 as lacking good in situ porosity data. The reported heat flow value is probably 30 percent too large a common correction value for clay-rich materials in situ.

B 3164 and B 2180, two very shallow wells from southeastern North Dakota, were the deepest wells available at the time this study was conducted. Both wells yield a conductive heat flow of 0.8 ± 0.3 HFU. These wells lie close to a gravity low (see Figures 4 and 10) which when extended into central Minnesota seems to be associated with low heat flow, 0.89 HFU (Roy and others, 1972). This low seems to be associated with granitic gneissic zones (Muehlberger and others, 1967).

B 4810 (Figure 3 and Table 2) yields a higher than normal heat flow 1.54 HFU when corrected for in situ porosity. The second method's results, 1.6 HFU, agrees to within experimental limits, ± 0.15 HFU, with the first method's results.

B 4509 is listed twice in Table 2 because it was logged twice; the June 19, 1976 log shows evidence of disturbance from linearity and this temperature data is suspect. The March 31, 1976 log is considered the better value for the conductive heat flow, 2.0 HFU (Figure 4). Because no in situ porosity data was available the reported heat flow value at this site could be as much as 30 percent too high.

Both temperature logs for well B 4811 seem to indicate higher than normal heat flow but the October log shows an unexplained thermal transient which lowers the heat flow values calculated using the interval method. The March 27, 1976 log (Figure 6) provided the heat flow for Figure 4.

The value of heat flow for B 4485 of 0.9 HFU was calculated from the March 31, 1976 temperature log (Figure 3) which shows a smooth temperature profile below 50 meters. The second log, October 5, 1976, shows a thermal disturbance at about 270 meters which seems related to a sand present at this depth (see Randich, 1975). Without the obvious offset from linearity of the two temperature values near 270 meters it would be difficult to decide which heat flow value represents conductive transfer. The October log is less likely to be representative of the conductive heat flow than the smooth profile measured in March. Samples for measurement of thermal conductivity for this well were not available. Thermal conductivities used here were projected stratigraphically from well B 3433, 46 km to the northwest.

Well B 4511 presents a problem because the two values of heat flow obtained from two logs of the well differ by 0.3 HFU. No samples were available from this well so thermal conductivities from B 3433, 40 km to the northwest were used. Because differences in the two temperature depth profiles caused a significant difference in the heat flow value, the heat flow value from this site was assigned to category 3.

B 3690 is the 1.1, ± 0.2 HFU value on the map just west of 103° W longitude (Figure 4) and is an average of both methods of computing the heat flow. Because there were no samples for this site, thermal conductivities used were from well B 4811, 26 km to the southwest. The thermal conductivities used were already corrected for in situ porosity and were stratigraphically projected to B 3690.

Well B 3433 yields a heat flow value of 0.9 ± 0.1 HFU and is, within experimental limits, in good agreement with the second temperature log. There is a thermal disturbance at about 350 meters depth which was avoided when calculating the conductive heat flow. This unusually high temperature value appears to be associated with a sand (see Croft, 1970) and an aquifer, but aside from this association the phenomenon is unexplained.

B 4662 (Figure 3) is a shallow well in which the heat flow was found to be 1.1 ± 0.1 HFU.

The heat flow value for well B 3558 is 1.1 ± 0.1 HFU when both methods of computing the heat flow are averaged. In situ porosity data was applied to the thermal conductivities and the heat flow values obtained agree to within experimental precision.

A 2894 is an oil well for which thermal conductivity measurements were made in at least one interval in most of the major stratigraphic units present (see Carlson and Anderson, 1966 for stratigraphy used). The temperature data along with the heat flow computation was presented in Figure 2 to show the effect of a correction based on in situ porosity data on the value obtained for heat flow. Thermal conductivities range from near 2.0 to 6.0 millical/cm sec°C with most values in the 2.0 to 4.0 millical/cm sec°C range. This evidence suggests that the sediments act as a thermal blanket assuming thermal conductivities in the igneous and metamorphic rock basement below the Williston Basin are typically in the 6.0 to 8.0 millical/cm sec°C range.

Three lines in the table were devoted to A 2894. The first line is heat flow with thermal conductivity uncorrected for in situ porosity, the second is heat flow corrected for in situ porosity and the third is a heat flow value determined from the upper part of the well using temperatures measured with the shallow well logging apparatus. The first and second lines include temperatures measured with the deep well apparatus. The best value of heat flow for this well is 1.51 ± 0.15 HFU. No drilling disturbance correction was necessary since more than eleven years had elapsed since well completion.

B 4812 (Figure 3) is a shallow water well approximately 24 km west of the previously discussed well A 2894. The heat flow value from B 4812 is 1.6 ± 0.34 HFU. The two heat flow values for wells A 2894 and B 4812 agree to within experimental uncertainties. This supports the hypothesis implicit in this study, that heat flow determinations based on data from water wells are a reasonable measure of the conductive heat flow for their respective sites.

Water well B 4599 gives a heat flow value of 1.08 ± 0.11 HFU.

B 4814 and B 4815 are wells located within 30 meters of each other. Both wells were logged in March 1976 and again in April 1976. The March temperature logs for both wells are relatively smooth and suggest a 1.71 ± 0.2 HFU value. The April 23, 1976 temperature logs show evidence of thermal disruption of unknown cause.

Well B 3991 is a well located in eastern North Dakota which had been logged on three separate occasions. There was no in situ porosity data for the well. The heat flow values for the February 22 and March 14, 1975 temperature logs show fairly consistent results, but the July 27, 1975 temperature log shows evidence of a hydrologic disturbance between 96 and 112 meters depth. The conductive heat flow value obtained from the July log is clearly inconsistent with the values obtained from the other logs. The heat flow values of 1.3 and 1.5 HFU could possibly be 30 percent too high because thermal conductivities were measured in clay-rich materials and in situ porosity data was unavailable.

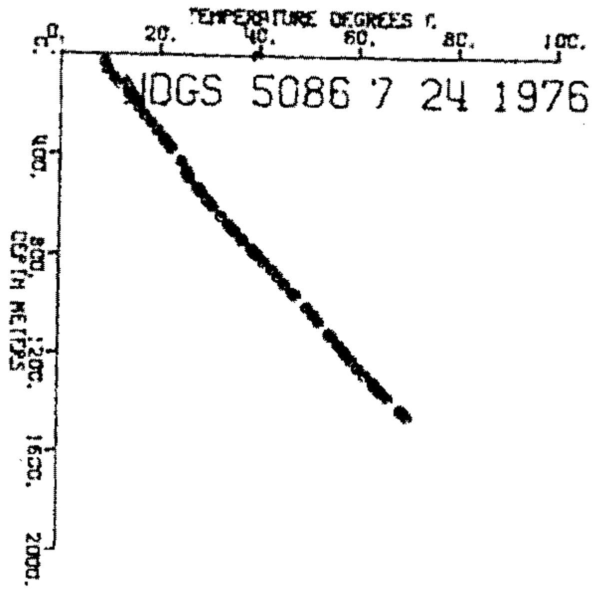
B 3575 was logged in April and again in May 1976. The best heat flow value for well B 3575 (Figure 3 and Table 2) is 0.94 ± 0.1 HFU calculated from the May data. The April 22, 1975 temperature log shows evidence of thermal disruption of unknown origin.

B 4597 is a shallow water well which gives a heat flow value of 1.3 ± 0.2 HFU. Good agreement is observed between the results of both methods of calculating the heat flow. This reported value is an average heat flow from both methods.

The value of the heat flow from oil well A 5086 (Table 2 and Figure 5) has been determined from study of the differences between open hole temperature logging versus maintaining the wellhead pressures by logging through a lubricator. The lubricator maintains the fluid column in the well statically while the logging cable is fed through a grease-packed rubber jacket enclosed in a grease-filled tubular housing. During open hole logging, the flow rate of liquid from this well was relatively small, 10 ml per sec, (escape of gas was not measured). Although the flow rate was small, the heat flow is affected by 0.05 HFU. Since the heat flow value measured using the lubricator is 1.62 HFU versus 1.55 HFU from the flowing case, the increase in heat flow is due to a 2 to 4 °C/km increase in the static well thermal gradients. This difference is smaller than the statistical uncertainty in the heat flow value (± 0.09) and certainly smaller than the known 10 percent uncertainty (± 0.16 HFU) from the technique used for measuring thermal conductivity (Sass and others, 1971). Thermal conductivities were corrected for in situ porosity using a resistivity log and a sonic log. The sonic log was available below the depth to which temperature measurements could be made. Since the sonic log and part of the resistivity log covered the same depth interval, the sonic log was used to scale the resistivity log for total porosity in that interval. That scale was applied to the resistivity log to give a value for in situ porosity where needed and this procedure allowed use of the resistivity log to correct the thermal conductivities.

Well A 5086 had over three years between well completion and temperature measurements. Although two months of production occurred

Fig. 5. Temperature - Depth Plots for Well 5086. Temperature plotted against depth for well 5086 (Barnwell Oil 1-16) in western North Dakota. The numbers following the NDGS well number (5086) are month, day and year of the temperature log. The upper plot (7/24/1976) is from temperature measurements made while fluids were maintained static in the well by the use of a grease-injection lubricator. Because a heavy sinker bar utilized to pull the wireline through the lubricator became jammed in the casing at the last temperature shown, no further temperature measurements were made below this depth with the lubricator apparatus. The lower plot (7/14/1975) shows temperatures measured while well was flowing.


TEMPERATURE DEGREES C
0.
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80.
100.
NDGS 5086 7 24 1976
400.
800.
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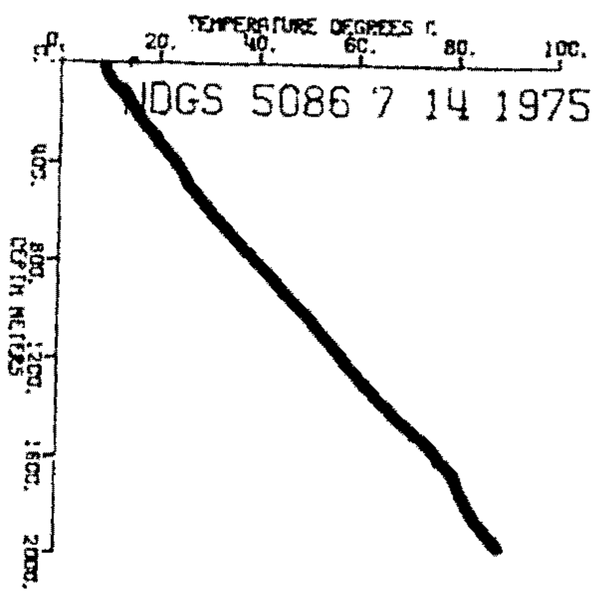
1600.
2000.
DEPTH METERS


TEMPERATURE DEGREES C
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NDGS 5086 7 14 1975
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DEPTH METERS

soon after well completion, the well had been undisturbed for two years before any temperature measurements were made.

Data for the first two lines of well A 5086 in Table 2 were collected with the deep well apparatus. The third line for A 5086 is an estimate of the heat flow from a shallow well apparatus temperature log for which few samples were available for thermal conductivity measurements.

Well B 2615 (Figure 6) in eastern North Dakota is a very shallow water well. The interval method calculations were affected by what appears to be a hydrologic effect which caused distortion in the calculated heat flow value. The second calculation of the data for B 2615 gives a more representative value of the heat flow because the two temperatures which appear to be anomalous have been ignored for the calculation. Since the second method gives the most consistent results, 0.55 ± 0.2 HFU this value has been rounded off to 0.6 HFU and used on the map (Figure 4). The B 2615 value is a category 3 value.

B 2430 (Figure 6) is also in eastern North Dakota 24 km from B 2615. The value of heat flow here is 0.6 ± 0.2 HFU and the uncertainty is large even though the statistics seem to indicate otherwise. The statistics were ignored in this case because the well was very shallow.

Included in Table 2 are heat flow results from five industry surveys on oil wells A 35, A 424, A 1099 and A 1139. Temperatures for these logs were measured within six days of the drilling termination date. Since all of these holes were drilled for oil exploration or development to considerable depths, all of the holes took at least one month to drill. The problem of drilling disturbance has been studied by Lachenbruch and Brewer (1959) and Jaeger (1961). It is clear these temperatures require a drilling disturbance correction. However, details of the drilling required to do this are unavailable. Therefore, large uncertainties have been placed on these five values of heat flow in lieu of the drilling disturbance correction.

A 591 and A 1099 give estimates of 1.0 and 1.1 HFU respectively in the Niobrara and Greenhorn Formations with an estimated shale conductivity of 4.0 mcal/cm sec °C. A 35 and A 424 provide estimates of 1.3 and 1.4 HFU respectively in the Sundance and Piper Formations again assuming 4.0 for the thermal conductivity. These four wells are all on the Nesson anticline within 8 km of each other and all four heat flow results averaged together give a value of 1.2 HFU. This value of heat flow may be low since it has not been corrected for the disturbance due to drilling but a correction for the porosity of these rocks in situ would also have to be made. To some extent, these corrections would compensate for each other. However, the uncertainty in these heat flow values is large.

Another important source of uncertainty is the estimated thermal conductivity of 4.0 mcal/cm sec °C. This value of thermal conductivity allows a reasonable estimate of heat flow to be made in wells A 591 and A 1099 (1.0 and 1.1 HFU) because the available temperature data occurred within the stratigraphic section composed of shale. The use of this value of thermal conductivity may not be as reasonable for wells A 424 and A 35 (1.3 and 1.4 HFU) because the available temperature data occurred within a part of the stratigraphic section composed of sandstone, limestone, some shale and minor amounts of salt and anhydrite (Carlson and Anderson, 1966).

Very shall water well B 3830 was logged in the winter and again in summer. Although both values of heat flow are uncertain, the 0.8 HFU value was the one used on the map simply because the temperature depth plot was somewhat more smooth than the winter log. Three measured thermal conductivities gave values of 4.0 millical/cm sec°C. These values are uncorrected for porosity.

B 3825 gives a heat flow of 1.4 HFU and can only be considered an estimate because no samples were available for thermal conductivity. Thermal conductivities used here were those of B 3830.

B 3842 is north of B 3830 and the thermal conductivity from B 3830 was also stratigraphically projected to the appropriate depths in B 3842 to give a heat flow value of 0.9 HFU. This value is an average of both method 1 and 2 results.

The temperature profiles for oil wells A 3479 and A 3342 were measured by Combs (1970) and published by Combs and Simmons (1973). In that paper, the thermal conductivity was estimated at 4.0 mcal/ cm^2sec°C. In this report, the heat flow values were recomputed using the temperatures from Combs' (1970) dissertation and measured thermal conductivities on samples from wells less than 1 km away from the respective sites.

The site in western North Dakota, A 3479 shows a difference in heat flow from top to bottom of the liquid filled portion of the well. Two explanations are possible. First, the thermal conductivity measurements are inadequate for the lower part of the well. Second, the temperature measurements are biased because of the five year production of oil from this well immediately preceding measurement of temperature. Because of these uncertainties, the value (1.6 ± 0.2 HFU) (see Table 2) was not used on the map Figure 4.

The other recomputed value of heat flow from Comb's (1970) temperature data, well A 3342 yields a heat flow value of 1.7 ± 0.2 HFU. A nearby site available from NDGS well log files, well A 1139 gives an estimated heat flow of 1.0 ± 0.5 HFU. This data is used for comparative purposes and it seems to indicate a large contrast in heat flow in a distance of 18 km. These sites in north central North Dakota will be discussed in the section on heat production.

The map of heat flow values (Figure 4) shows that even though high quality measurements are few, the lower quality data when used with the higher quality data leads to a consistent pattern of heat flow. This is particularly true in southwestern North Dakota where the data is sufficiently distributed to give a coherent picture. All of the heat flow values west of 103° west longitude are higher than normal (>1.5 HFU) heat flow with one exception. East of 103° W only five values of heat flow are greater than 1.5 HFU. Four of these occur at sites for which no in situ porosity data was available to correct thermal conductivity values. The heat flow values are possibly too large by as much as 30 percent, a common correction value for clay or shale porosity. The only exception is the value recomputed here from the Combs (1970) temperature data which will be discussed further below.

HEAT PRODUCTION AND ITS RELATIONSHIP TO HEAT FLOW IN NORTH DAKOTA

Introduction

The heat flow (q) from plutonic rocks along with the heat production (A_o) has been used to develop the concept of the heat flow province (Roy, Blackwell and Birch, 1968). The heat flow from each province generally depends to a first approximation on the radiogenic heat production of surface rocks according to the following linear relation (Birch, Roy and Decker, 1968; Roy and others, 1968; Lachenbruch, 1968).

$$q = q^* + DA_o \tag{7}$$

where q is the measured surface heat flow and A_o is the measured heat production in HGU. A heat generation unit or HGU is equal to 10^{-13} cal/cm^{3}sec. Intercept value q^* and slope D have the respective dimensions of heat flow and depth and are considered uniform throughout each province.

This linear relation is the basic assumption upon which these analyses are based (Lachenbruch, 1970). For the Basin and Range province the value of q^* and D are 1.4 HFU and 10 km respectively and for the Eastern United States province the values are 0.8 HFU and 7.5 km. The second term of the linear relation is equivalent to the steady heat flow that would be produced by a uniform 10 km block of crust (Roy and others, 1968).

The second term of the linear relationship is determined by multiplying by 10 km the heat production determined by a laboratory measurement on crustal samples. The expected heat flow is determined by adding the appropriate q*, 1.4 for Basin and Range type of heat flow and 0.8 for Eastern United States heat flow. Lachenbruch (1968, 1970) has shown that the linear relationship is unaffected by differential erosion in any province if and only if the heat production instead of being uniform to depth D varies with depth Z according to $A_0 \; e^{-Z/D}$. In this interpretation, q* is most naturally identified as the contribution from the mantle. The second term of the linear relation can then be considered the crustal contribution to the heat flow. Knowledge of province parameters (q*, D) and an assumption of thermal conductivity allow calculation of temperatures to depths of tens of kilometers.

The variation in surface heat flow one would expect to observe in sediments above an igneous and metamorphic rock basement should reflect changes in basement rock heat production (Roy and others, 1968). Also, regional patterns could be established with relatively few measurements of heat flow and heat production (Roy and others, 1972).

North Dakota Basement Rock Heat Production Samples

Gamma ray spectroscopy was used to analyze basement rock samples from six sites. Four of the sites provided core and two of the sites drill cuttings. While many more basement samples were available, especially in eastern North Dakota, these six were selected because they were of good quality and a large quantity of material was available. The basement rock heat production analyses reported in Table 2 were done by Carl Bunker at the United States Geological Survey in Denver, Colorado.

Gamma ray spectroscopy determines the quantities of uranium, thorium and radioactive potassium (K_{40}) in the rock. The gamma ray emission process produces heat so that the quantity of heat produced is related to the amounts of naturally occurring radioactive elements in basement rocks. The data shown in Table 3 gives the NDGS well number; indicated by A followed by the well number.

The location columns consist of latitude and longitude each listed in degrees to the nearest minute. Table 3 lists the rock type encountered at the basement surface. Table 3 also shows the measured density of core and crushed rock. The table lists HMU (10^{-6} cal/gram year) value from the analysis of the natural radioelement concentration. The heat generation (HGU) value is listed with its low and high computed from the two density values. The remaining part of Table 3 shows the heat flow values and their respective distances from that heat production site. The uncertainty in the HMU value is less than 5 percent. The uncertainty of the heat generation value is larger than 5 percent and is directly related to the uncertainty in the measured density.

Heat Flow and Heat Production Sites

One of the major difficulties with the great number of basement sampled sites in eastern North Dakota was the problem of obtaining wells deep enough for acceptable temperature measurements. Fewer basement samples were available for western North Dakota and while there were greater numbers of oil and water wells which were deep enough, the problem became one of finding wells accessible for temperature measurements

TABLE 3

HEAT PRODUCTION AND HEAT FLOW DATA FOR NORTH DAKOTA SITES

Well No.	Location Latitude Deg.	Latitude Min.	Longitude Deg.	Longitude Min	Sample depth m	Rock Type	Measured Density (g/cc +/-.1) core	Measured Density crushed	HMU ++ Value 10^{-6} cal/ gm yr	HGU Value 10^{-13} cal/ cm sec low	HGU high	Distance km to Heat Flow near	Distance far	Heat Flow 10^{-6} cal/ cm^2 sec. low	Heat Flow high
A 1231	48°	17	102°	59	4148.	Orthopyroxene Granulite	2.5	2.8	5.38	4.26	4.78	3.2	9.6	1.1*	1.3*
A 2219	48°	48	100°	58	2220.	Andesine-Hornblende-Schist	2.7	2.9	1.36	1.16	1.25	6.4	17.6	1.**	1.7
A 16	46°	17	100°	43	1634.	Biotite-Hornblende-Gneiss	2.8	2.5	3.16	2.51	2.81	19.2	27.2	1.2+	1.2+
A 29	46°	56	97°	37	549. to 624.	Granite	-	2.2	1.49	1.04	-	5.6	19.2	0.6+	0.6+
Pembina	48°	42	97°	37	398.	Iron Formation	3.11	2.95	1.27	1.19	1.25	6.4	11.2	0.8	0.9
A 3268	46°	52	103°	25	4130. to 4191.	Biotite Granodiorite	-	2.44	5.6	4.33	-	32.0	36.8	1.5	1.9
A 3268	46°	52	103°	25	4130. to 4191.	Biotite Granodiorite	-	2.44	5.6	4.33		25.0		1.1	

*Average heat flow of two wells from the NDGS well log files.

**The 1.0 HFU value is preferred here because it is considerably closer to the heat production site even though the 1.7 value is apparently less uncertain.

+Values of heat flow determined in shallow well.

++Data listed by element in Appendix B.

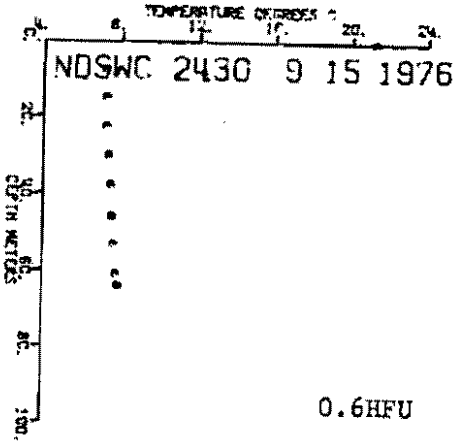
near to sites where basement samples were available.

The six sites met the criteria of being well distributed about the state, adequate basement material was available and heat flow information could be obtained from nearby wells. The disadvantages were that the wells available for heat flow measurements were not the same site as that which provided the heat production data and that at three of these sites the basement rocks were metamorphic rocks. It is not known how representative the heat production data is for the crust beneath the metamorphic rock sites.

Discussion of Individual Heat Flow-Heat Production Sites

Figure 6 shows six selected temperature depth plots for three of the heat production sites. The first two, NDSWC 2430 and 2615, are in the Grand Forks area (Gfk on map, Figure 7). Both plots indicate relatively low temperature gradients for the overall temperature depth curves. The temperature difference between the two wells is attributed to the location of B 2430 on the southern bank of the English Coulee, a tributary of the Red River, which forms the eastern boundary of the state of North Dakota. Such anomalous surface conditions have been analyzed by Lachenbruch (1950). Aside from what appears to be a surface hydrologic effect in B 2615, both show similar overall temperature gradients but the resulting heat flow (0.6 HFU) could be too low for both wells because of the relatively recent (last 10, -14,000 years, Moran and others, 1973) deposition of the glacial Lake Agassiz sediments. Calculations using the analysis of Birch and others (1968) for sedimentation indicate that thermal gradient corrections would raise

Fig. 6. Temperature-Depth Plots from wells near three of the heat production sites. Six temperature depth plots representing three heat flow - heat production sites. NDSWC 2430 and NDSWC 2615 are in eastern North Dakota hear Grand Forks (Gfk) NDSWC 4501 and NDSWC 8912 are in south-central North Dakota in Emmons County (E). NDSWC 3690 is in western North Dakota (Bsk). NDSWC 4811 is also in western North Dakota (Bsl). See text for explanation.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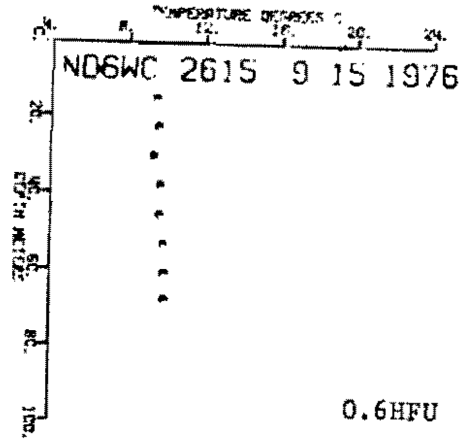
NDSWC 2430 9 15 1976
DEPTH METERS
0.6HFU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DEPTH METERS
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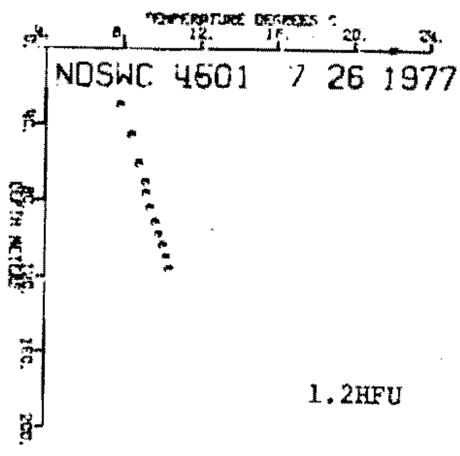
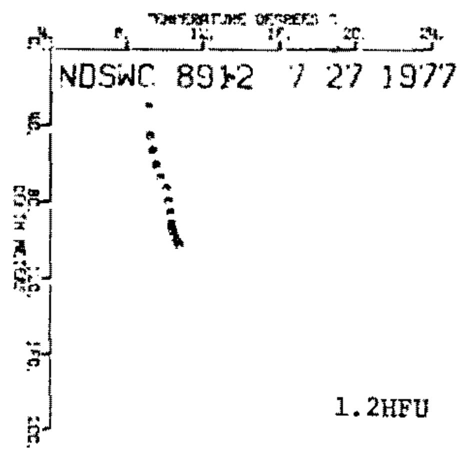

TEMPERATURE DEGREES C
NDSWC 4601 7 26 1977
DEPTH METERS
1.2HFU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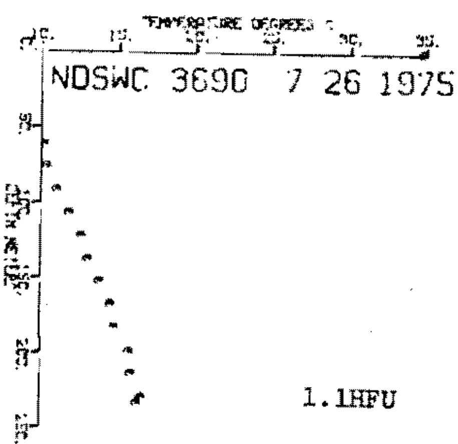
DEPTH METERS
1.2HFU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NDSWC 3690 7 26 1975
DEPTH METERS
1.1HFU

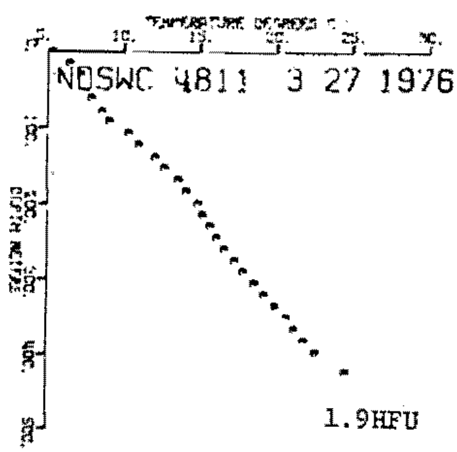
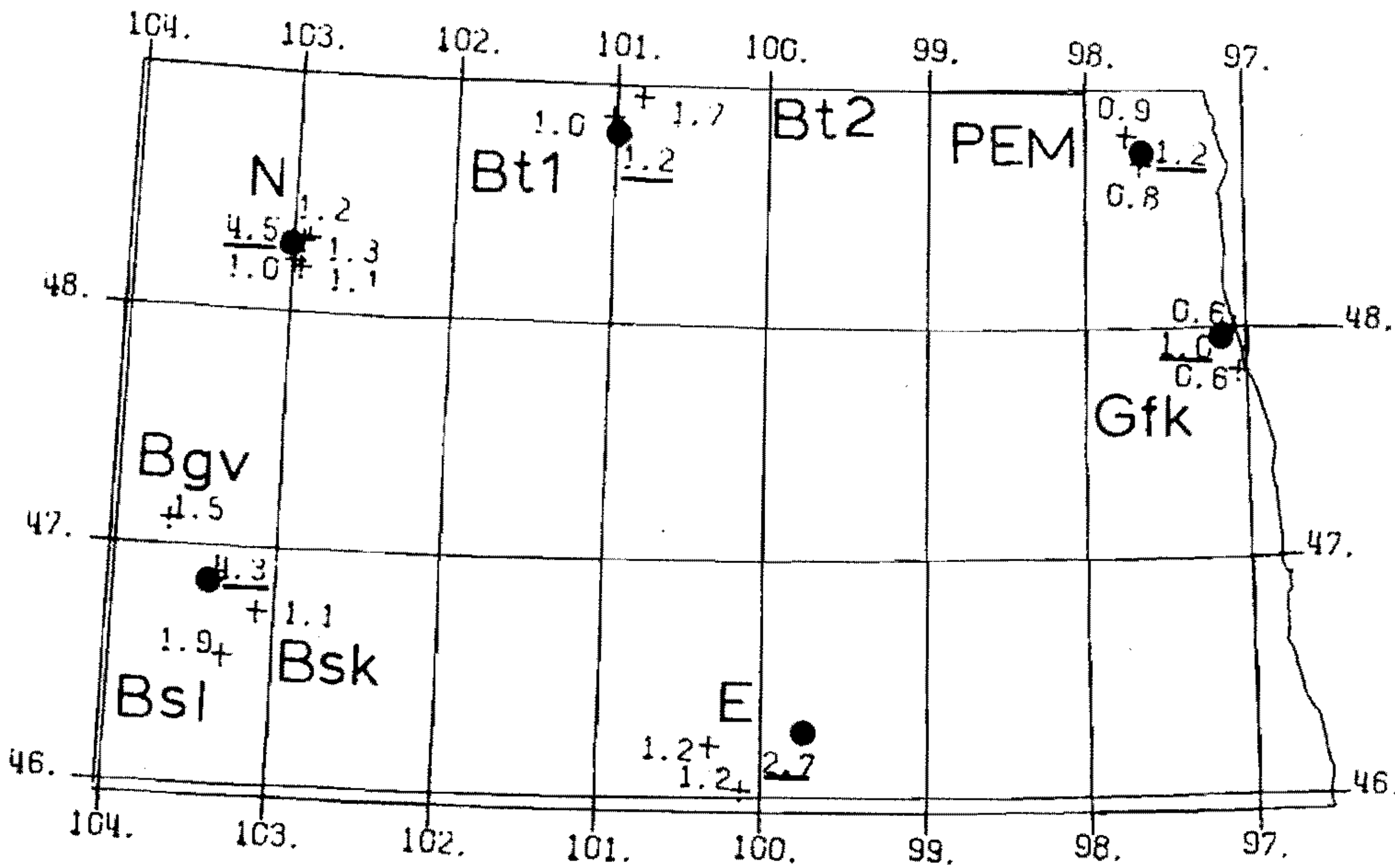

TEMPERATURE DEGREES C
NDSWC 4811 3 27 1976
DEPTH METERS
1.9HFU

Fig. 7. Heat Flow and Heat Production Sites in North Dakota. Heat flow values in HFU are shown with heat production values (underlined) in HGU. Crosses are heat flow well sites; solid circles are heat production sites. The data labelled PEM is from the Pembina county area of northeastern North Dakota. Gfk is data from the Grand Forks area. E is from south-central North Dakota's Emmons county area. Bt1 and Bt2 are from north-central North Dakota's Bottineau county area. Bsk, Bsl, Bgv are southwestern North Dakota combinations of the Billings county heat production value with Stark, Slope and Golden Valley counties heat flow values respectively.


N
Bt1
Bt2
PEM
Gfk
Bgv
Bsk
Bsl
E
1.0
1.7
1.2
0.9
1.2
0.8
1.2
4.5
1.3
1.0
1.1
0.6
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46.

the value of the heat flow 0.1 HFU for these sites. Another possible explanation may be related to the Winnipeg group sedimentary rocks which subcrop the region beneath these two sites (see map by Carlson, 1969). A correction to the heat flow value was not made here because of the uncertainties due to the very shallow depth of the wells and the possible hydrologic effects. Deeper temperature data from this area should reduce the uncertainty in these heat flow values.

Well B 4501 and B 8912 (Figure 6) are in the Emmons county region of south-central North Dakota (E) (see map Figure 7). These temperature-depth plots show somewhat greater slope and therefore greater gradients than the data from the Grand Forks area wells. Even though these wells are very shallow, they still appear to give reasonable subsurface temperatures. The values of heat flow here are in the normal to low range of 1.2 HFU.

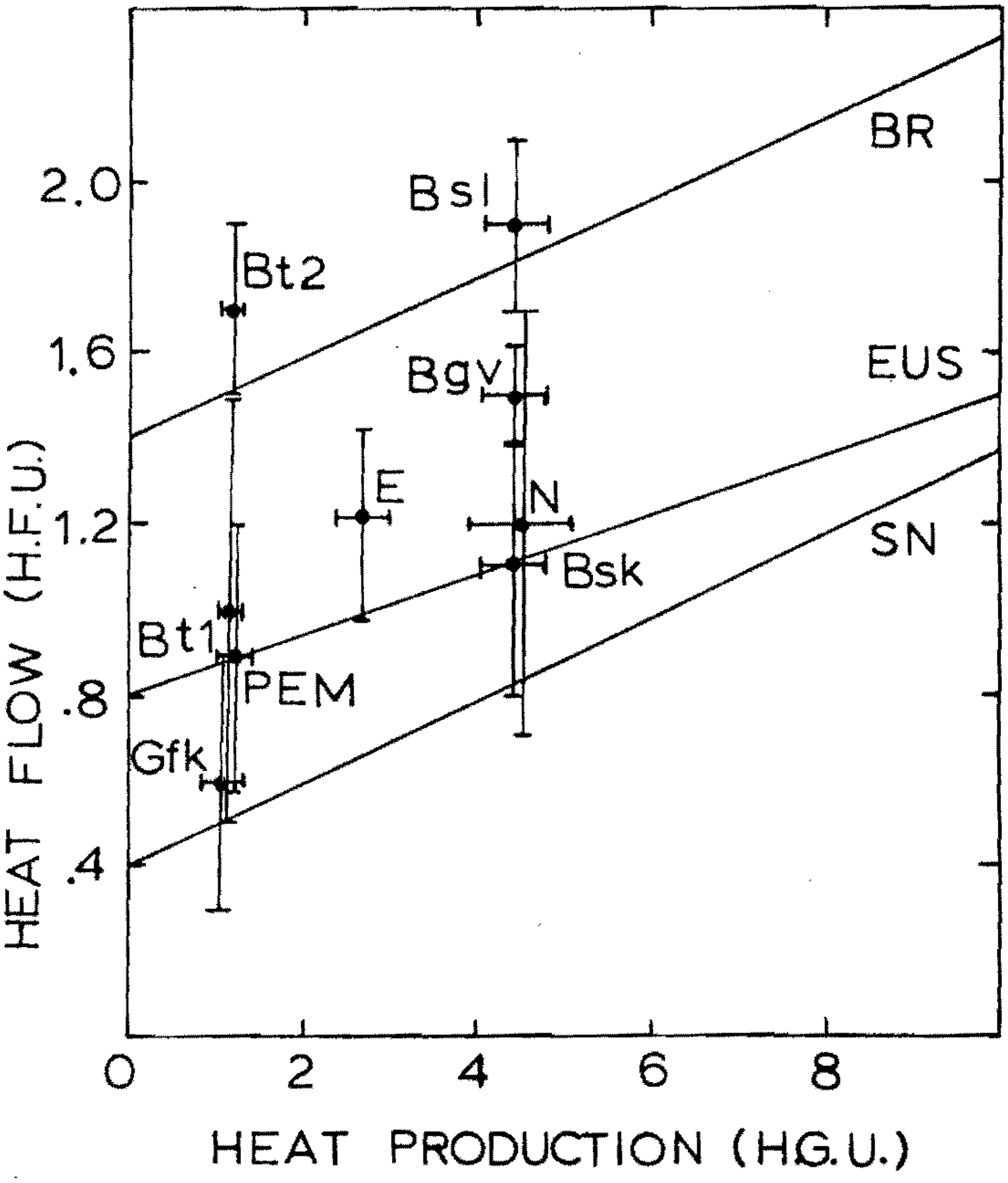
B 3690 and B 4811, Bsk and Bsl respectively (Figure 6 and map Figure 7) are two sites near the heat production value in southwestern North Dakota. B 4811 yields the highest heat flow of any well examined in this study.

The map of heat flow sites and values with their nearby associated heat production sites and values from the basement rocks is shown in Figure 7. In the eastern part of North Dakota the heat flow appears to be low to normal. If one assumes the validity of the linear heat flow heat production relationship (Lachenbruch, 1970; Lachenbruch, 1968; Roy and others, 1968a; Birch and others, 1968), then the eastern North Dakota sites, Pembina (PEM) and Grand Forks (GFK) are interpreted as eastern United States or normal heat flow (Roy and others, 1972). Eastern North Dakota lies on the edge of a stable Precambrian shield, so the low heat flow values in the Grand Forks area cannot be interpreted as a Sierra Nevada-like value and the explanation for the low value must lie in either rapid sedimentation or water flow beneath the sites into the nearby Red River. Even though the basement materials used for the Pembina (PEM) data point in northeastern North Dakota (Figure 8) are from iron formation (Richardson and Karner, 1975), a metamorphic rock, the point plots on the eastern United States line.

The site labelled E on the map (Figure 7) in south-central North Dakota has two similar heat flow values associated with it and the heat production site is a considerable distance away. In spite of this disadvantage, if the uncertainty for this value is as small as indicated here this point can also be interpreted as an eastern United States type of heat flow (see Figure 8).

The site in north-central North Dakota has been treated somewhat differently than the other sites discussed. For the previously discussed sites the heat flow values were averaged because they were within the experimental uncertainties of each other for their respective sites. For the sites labelled Bt1 and Bt2 in north-central North Dakota, there is such a large difference in heat flow that the points were plotted separately. The Bt1 value is an estimated heat flow from temperatures available from the NDGS well log files and while there are large uncertainties in the data for the point plotted in Figure 8, Bt1 would seem to be associated with eastern United States type of heat flow. This is the preferred interpretation for this site. The other value of heat flow, Bt2 recomputed from temperatures measured by Combs (1970), when used

Fig. 8. Heat Flow Versus Heat Production. Plot of heat flow versus heat production for three plutonic sites (Gfk, N, Bsk, Bsl, Bgv) and three metamorphic sites (PEM, E Bt1 and Bt2) within North Dakota. The straight lines represent previously determined relationships (Roy and others, 1968b; Roy and others, 1972; Lachenbruch, 1968).



BR
EUS
SN
Bsl
Bt2
Bgv
E
N
Bsk
Bt1
PEM
Gfk
2.0
1.6
1.2
.8
.4
0
2
4
6
8
HEAT FLOW (H.F.U.)
HEAT PRODUCTION (H.G.U.)

with the available heat production value could be interpreted as Basin and Range type of heat flow. The distance from the heat production site was the deciding factor. Obviously, a more detailed study of heat flow and heat production from this area would be helpful in resolving such problems. Indeed, the question of how large or small an area one needs to examine from the standpoint of heat flow and heat production to determine linearity is still largely unresolved especially in the study of the Basin and Range type heat flow-heat production province (Roy and others, 1972).

The area labelled N on the map (Figure 7) shows several sites from the Nesson anticline. The heat flow values at N are estimates based on temperatures from the NDGS well log files and estimated thermal conductivity. The four heat flow values have been averaged here but since the two lower heat flow values are from shales they may be more representative of the heat flow because the temperatures were measured in shale. The higher two heat flow values do not contain shales alone and the estimated thermal conductivity is more uncertain than that used for the lower heat flow values. Since this is the case, the lower values may well be more representative of the heat flow. With the relatively high (for North Dakota) heat production (see map Figure 7 and Table 3), it is difficult to see how this point could be interpreted as Basin and Range as long as the average heat flow value is used. If individual values are used with the arbitrarily large uncertainty due to the inability to correct for drilling disturbance, one would be forced to conclude that this site could be either Basin and Range or eastern United States. But, if the average value is used even with the arbitrarily large uncertainty, there is no overlap with a Basin and Range type of interpretation (see plot Figure 8). It is this interpretation for the Nesson anticline as Eastern United States type heat flow which is the favored interpretation. Less uncertain heat flow data from this area is needed to verify this interpretation. The other geophysical information discussed below may also help to resolve this question.

The southwestern North Dakota heat production site when used with heat flow values around it (Bsk, Bsl, Bgv) provides by far one of the most interesting sites (see map Figure 7). The three heat flow values are plotted separately because their differences are considerably larger than experimental error. The lowest heat flow value (Bsk) to the east of the heat production site indicates that this area is still eastern United States type of heat flow (see map Figure 7). This point falls on the Eastern United States line (Figure 8). The next value of heat flow to the west falls in the north-south region of heat flow where no heat flow value has been observed to be less than 1.5 HFU. This 1.9 HFU value (Bsl) when plotted with the heat production is interpreted as Basin and Range type of heat flow. This is the only point which may be interpreted with any reasonable certainty as Basin and Range type heat flow if the distance between the heat flow sites and the heat production site can be largely ignored.

Indeed, the 1.5 HFU value farther west, is also interpreted to be Basin and Range type because it falls in the north-south region where no heat flow value is less than 1.5 HFU even though the point plots as an intermediate value between Basin and Range and eastern United States type of heat flow (see Figure 8). If this is true it seems possible then, to plot a regional 1.5 HFU contour, indicating a region of higher mantle heat flow. This is in contrast to Roy and others, 1972 who used both 1.5 and 2.0 HFU contours to mark the boundary between heat flow provinces. The contrast may be a result of the reduction of heat flow value when in situ porosity data was applied to the termal conductivities. Hydrologic conditions (Houda, 1977), below the depth to which heat flow measurements were made, may also be important. However, in the absence of deeper heat flow data, speculation regarding the hydrology must be viewed cautiously.

Because of the uncertainties and the limited number of data points associated with any one province, the reduced heat flow value has not been formally computed here. The data has been plotted on Figure 8 with the province lines as determined by Roy and others (1972), and Lachenbruch (1968), and confirmed for the Sierra Nevada by Lachenbruch and others (1976). One could summarize the foregoing observations by the association of the heat flow-heat production data points with either the Eastern United States line or the Basin and Range line. Three sites, GFK, PEM, E, can be interpreted as eastern United States. N can be considered eastern United States if the average value of the heat flow is realistic.

This leaves only the north-central North Dakota sites Bt1 and Bt2 which can be considered a possible candidate for either eastern United States or Basin and Range type of heat flow province. To resolve this ambiguity more heat flow data is necessary from this area.

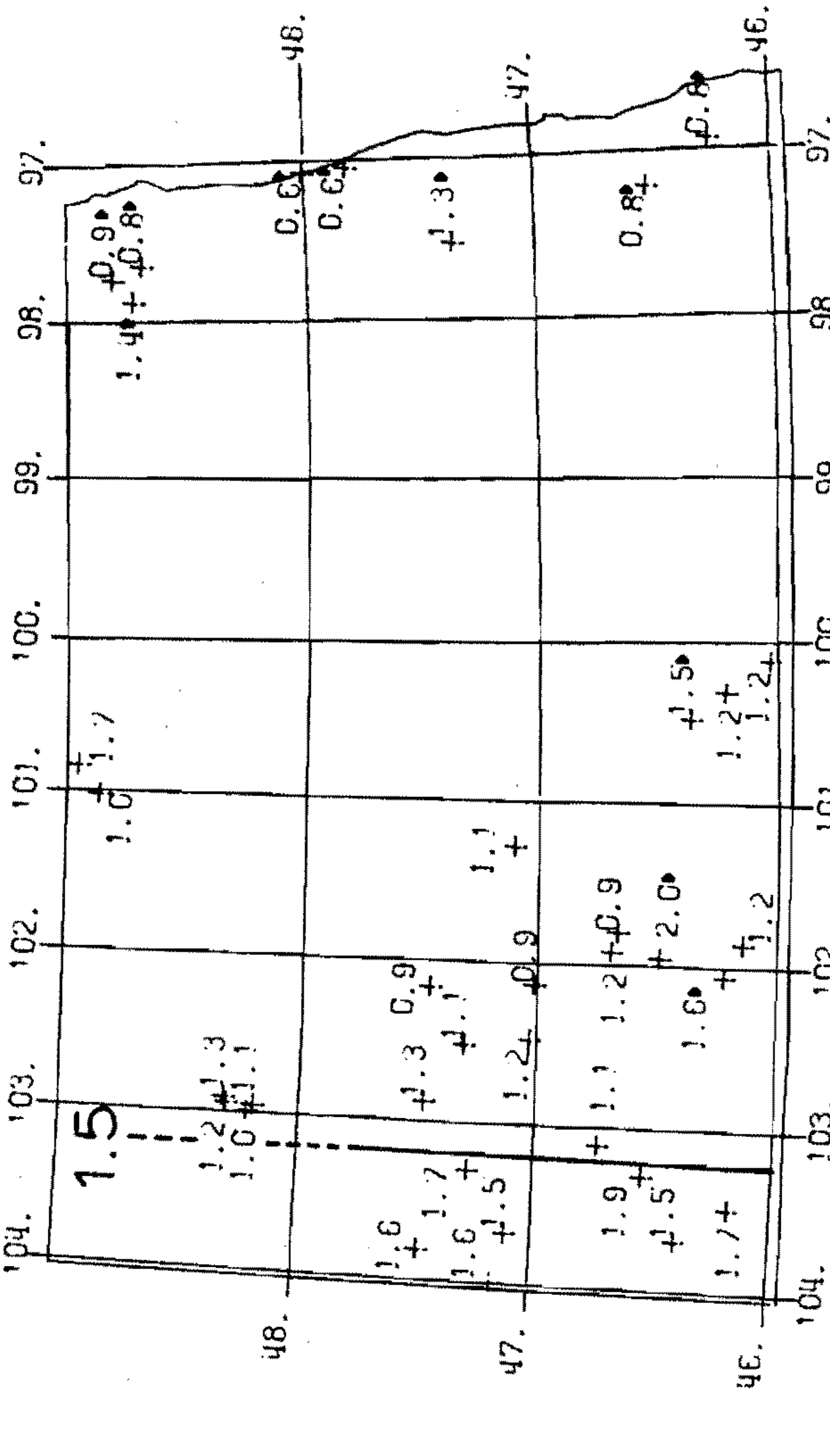
The recomputed value of heat flow from the Combs (1970) temperatures in north-central North Dakota presents an interesting problem.

Two solutions seem possible. First, the heat production in the basement rocks at Bt2 (1.7 HFU) is higher than any other value of heat production which has yet been observed in the basement rocks in North Dakota. If so, the site would be considered eastern United States type of heat flow. Second, if the nearby value of heat production to the south is representative for the Bt2 site, the site should be considered Basin and Range type of reduced heat flow. This would seem unlikely but this possibility cannot be discarded. The second possibility, a higher heat flow from the mantle (higher reduced heat flow), is required if the basement rock heat production is similar to the nearby heat production value. This problem will be further discussed in the section on other geophysical information.

The southwestern North Dakota sites Bsl, Bsk, Bgv are important. The eastern most site, Bsk, would seem to be interpretable as an eastern United States type of heat flow. The southern most site in this group, Bsl, would seem to be associated with the Basin and Range province type of heat flow. It is also important to note that this is a north-south region where no heat flow value is less than 1.5 HFU. The westernmost site, Bgv, is intermediate but, it too is in the region where no heat flow value is less than 1.5 HFU. Perhaps, the heat production value does not apply. Perhaps, there are hydrologic disturbances which lower the heat flow. Whatever the reason for its being intermediate, its association would seem to be Basin and Range type.

The heat flow map (Figure 9) shows a line which is interpreted as the 1.5 reduced heat flow contour. East of this line, all the wells have heat flows less than 1.3 HFU with three notable exceptions: B3627,

Fig. 9. Interpretation of Heat Flow and Heat Production Results. Numbers are heat flow values associated with the closest well location (crosses). Heat flow values which are uncorrected for in situ porosity are indicated by small triangles. Interpreted 1.5 heat flow contour is shown west of 103° west longitude and dashed where there is insufficient data.


97.
98.
99.
100.
101.
102.
103.
104.
48.
47.
46.
1.5

4509, 8117 yielding 1.6, 2.0 and 1.5 HFU respectively (see Figure 9). The important fact for these three wells is that no in situ porosity data was available for these wells and since the heat flow was computed in the clay-rich Hell Creek Formation, one could expect that these values would be reduced by 30 percent or about the order of clay or shale porosity. The implication is that these values would also be 1.4 HFU or less and strongly suggests that the 1.5 HFU contour or the heat flow transition is oriented north south passing just west of the 1.1 HFU value west of 103° west longitude line (see map Figure 9).

West of the 1.5 HFU contour the heat flow and heat production data seems to suggest Basin and Range type of reduced heat flow or higher mantle heat flow. Indeed, if the value of 1.1 HFU is not fortuitous but truly represents the heat flow at this site then, this site and the 1.9 HFU value southwest of it (see map Figure 9), represents a transition zone which is very sharp and on the order of 28 km. This is apparently not unlike the 20 km that has been observed by Roy and others (1972). It would appear the heat sources and or sinks present are at upper mantle or lower crustal depths (Roy and others, 1972).

OTHER GEOPHYSICAL INFORMATION

Introduction

The interpretation of the observed heat flow-heat production data would be strengthened if it could be shown to be consistent with the other available geophysical data. The primary question to be resolved is whether the 1.5 HFU contour extends east of the recomputed heat flow value from the Combs (1970) temperatures in north-central North Dakota or extends north-south as interpreted in Figure 9. The lack of heat flow information in northwestern North Dakota precludes an unambiguous answer to this question. The development of high quality heat flow-heat production information for northwestern North Dakota will be required to test the pattern proposed here.

The other geophysical information consists of a Bouguer gravity anomaly map (Wollard and Joesting, 1964), a map of anomalous electrical conductivity (Alabi and others, 1975), a map showing locations of earthquakes, microearthquakes (Erickson, 1970, and Needham, 1974) and crustal thickness (Warren and others, 1973). The maps presented here are all modified from the original source to focus on the relationships in North Dakota.

Bouguer Gravity Anomalies

In eastern North Dakota where the sedimentary cover thins to approximately 0.3 km (Carlson and Anderson, 1966), the gravity data

(Figure 10) appears to be strongly influenced by the basement lithology (see Muehlberger and others, 1967). In western North Dakota, there is relatively little basement lithologic information since 4.5 km of sediments are present (Carlson and Anderson, 1966) and basement samples are expensive to obtain. The important observations from the gravity data concerning western North Dakota are:

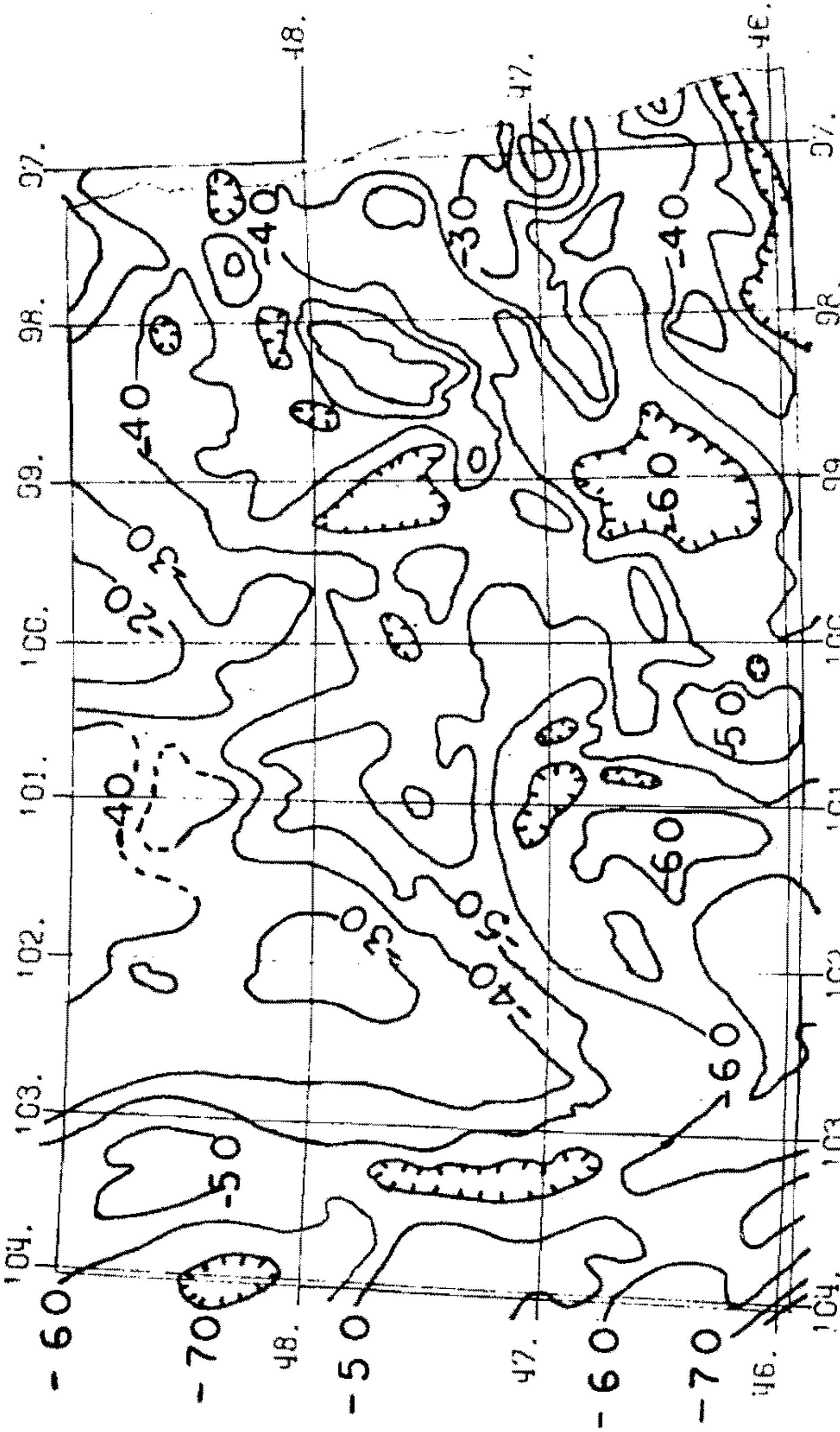
1. Thickness of the sedimentary cover seems to obscure details of basement lithologic patterns. Gradients are considerably less steep to the west than the gradients are in eastern North Dakota.

2. There is a regional north-south feature marked by both the -50 and -40 milligal contour lines near 103°W longitude. It has been observed before (Meuhlberger and others, 1967) and would be indicative of a regional intrabasement feature.

Electrical Conductivity

The electrical conductivity anomaly data presented by Alabi, Camfield and Gough (1975) correlates well with the heat flow results presented in this report. A comparison of Figures 9 and 11 shows that the heat flow is higher than normal slightly to the east of the demarcation chosen by Alabi and others (1975) to mark the eastern edge of the electrical conductivity anomaly. Its extent is north-south and coincides well with the heat flow results. Estimates of the width of the anomaly depended upon the location of the three component magnetometers; the relevant ones are shown in Figure 11. Since the spacing of the instruments was great, the heat flow data presented here probably provides a better estimate of the position of the eastern edge of the anomaly. One of the problems with the models of Alabi and others

Fig. 10. Bouguer Gravity Anomalies in North Dakota. Bouguer gravity anomalies are shown in milligals for North Dakota (modified after Wollard and Joesting, 1964).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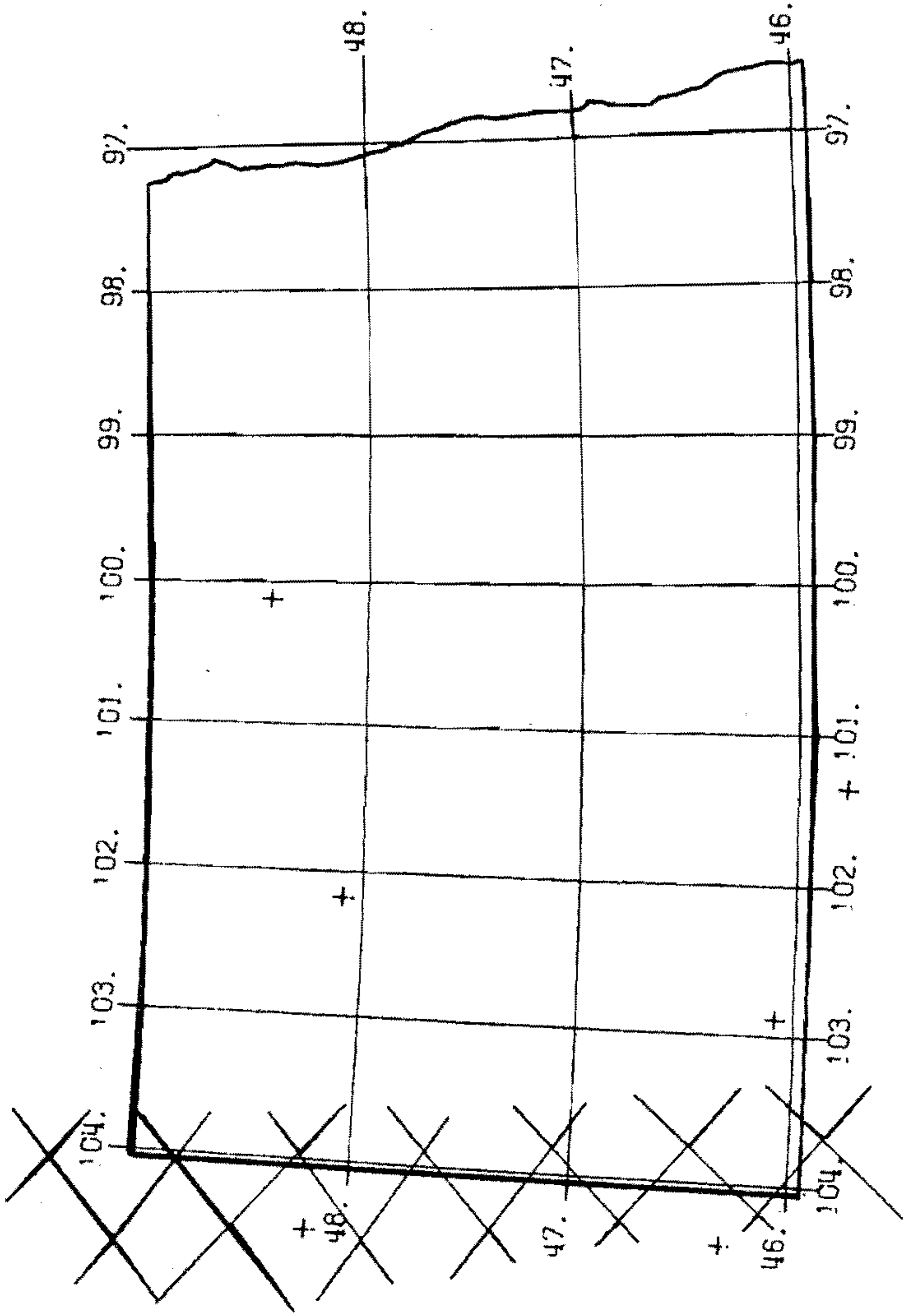
100.
101.
102.
103.
104.
48.
47.
46.
-60
-70
-50
-60
-70
-40
-30
-20

Fig. 11. Anomalous Electrical Conductivity in North Dakota. The area around 104° west which is cross hatched indicates the area of western North Dakota showing anomalous electrical conductivity. The feature is part of the North American Central Plains Conductivity anomaly. Crosses show locations of pertinent three component magnetometer sites. Modified after Alabi and others (1975).


97.
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102.
103.
104.
48.
47.
46.

(1975) was the difficulty in fitting the observed field in that lateral and vertical components were fit well but phase and frequency could not be matched simultaneously. It appears that adequate geometric information on the conductor is necessary to model it completely. There is clearly anomalous behavior when the data is plotted as a function of time. Their interpretation of the depth to the anomaly suggests that it starts in the lower crust but that most of the conductive body lies in the upper mantle within the lithosphere with a thickness of 100 km.

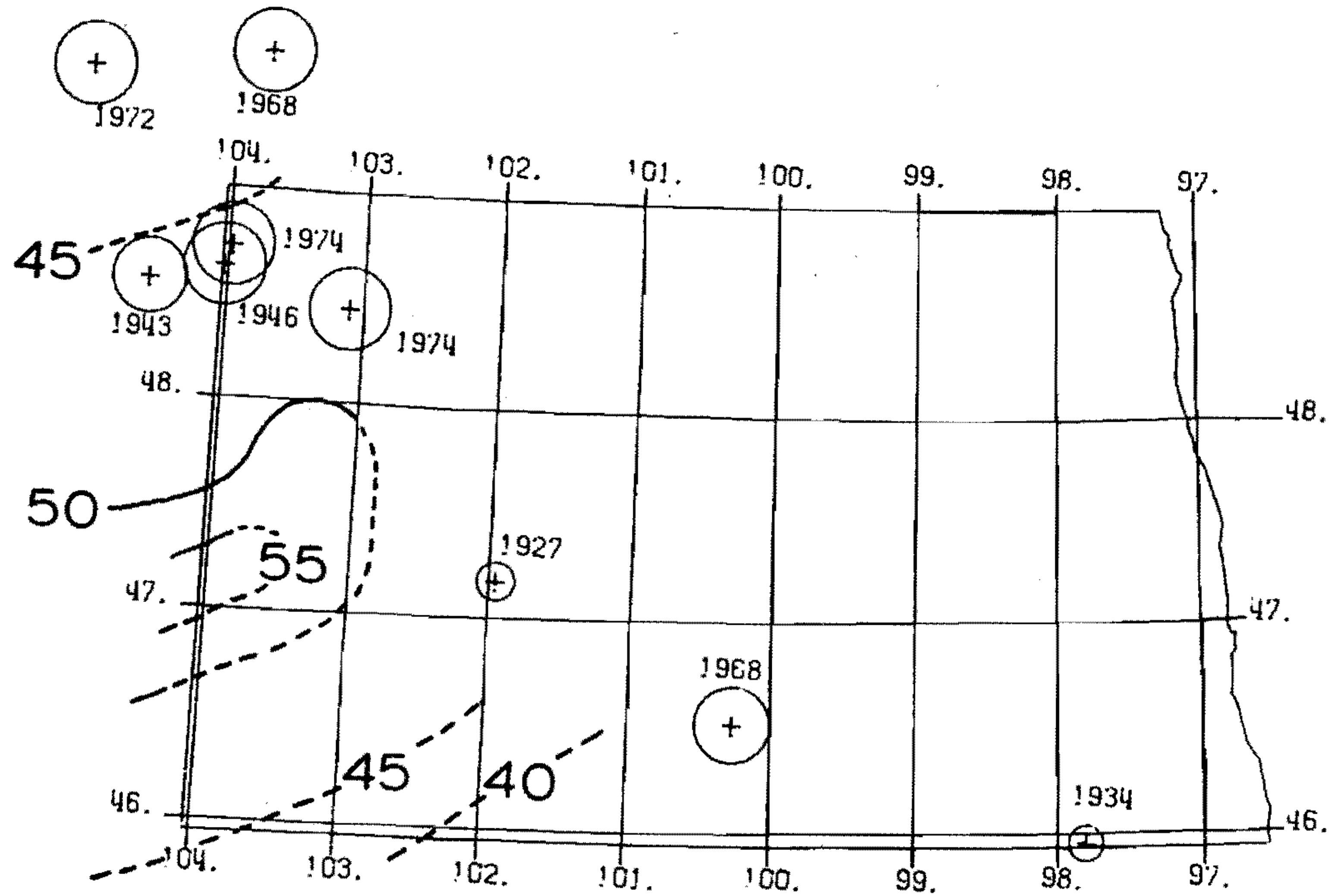
Active and Passive Seismic Data

Alabi and others (1975) also suggest that two out of three earthquake epicenters in southern Saskatchewan mark the edges on either side of the electrical conductivity anomaly.

Figure 12 shows the known relevant earthquake epicenters for North Dakota from Erickson (1970), Alabi and others (1975) and Needham (written communication, 1974). The locations of earthquake epicenters prior to 1968 are all from macroseismic information (Mercalli intensity). The 1968 event in central North Dakota was the first instrumentally located earthquake. The two 1974 events were microseisms detected by the large amplitude seismic array (LASA) (Green, Frosh and Romney, 1965) and obtained from Needham (1974). The primary limitation of the 1974 microseisms is the fact that the LASA was designed to screen out information that is less than 10 degrees from the array to avoid system overload from the Yellowstone area. It is recommended that the reader use the information on Figure 12 carefully because of the large uncertainties. The epicenters (crosses) show the approximate center of the disturbance and the surrounding circle indicates the probable

Fig. 12. Seismic Data in North Dakota. Earthquake epicenter estimates (crosses) with their uncertainty (circles) are shown for North Dakota and associated region. Pre 1968 events are from macroseismic data; post 1968 events are instrumentally located. Sources of the data are Erickson (1970), Alabi and others (1975) and Needham (personal communication, 1974).

Isopleths are crustal thicknesses in kilometers determined from seismic refraction data (Warren and others, 1973). Note that they are mostly dashed indicating that they are inferred.


1972
1968
104.
103.
102.
101.
100.
99.
98.
97.
45
1974
1943
1946
1974
48.
50
1927
55
47.
1968
45
40
46.
1934

uncertainty in the epicenter location. While this data is somewhat crude, it does suggest that there has been more earthquake activity in western North Dakota and several of the events are associated with the region of the electrical conductivity anomaly. Crustal thicknesses in kilometers are also shown on Figure 12 from seismic refraction data of Warren and others (1973). The interpreted crustal thicknesses are greatest (45 to 55 km) where the heat flow has been identified as high. The heat flow data east of 103° W is more normal and seems to correspond to a slightly thinner (40 to 45 km) crust.

The following inferences are drawn from the other geophysical information.

1. There is good areal correlation between the higher than normal heat flow data, the electrically conductive body mapped by Alabi and others (1975), and the southern part of the -50 milligal gravity contour. While the data on earthquakes and microearthquakes is limited, it does suggest that the extension of the higher heat flow region should be to the north slightly west of 103° W longitude and not east of the high heat flow value of Combs (1970) in north-central North Dakota.

INTERPRETATIONS AND CONCLUSIONS

Figure 13 shows temperature as a function of depth for the heat flow data for an area of southwestern North Dakota bounded in the north south direction by 46° and 48° N latitude and bounded east west by 100° and 104° W. The area has been subdivided further by the interpreted 1.5 HFU contour in Figure 9 which allows averaging of seven heat flow values west of the 1.5 HFU province transition and eleven heat flow values east of the transition. On Figure 13 the regions have been designated Basin and Range (BR) type and eastern United States (EUS) type of heat flow. The solid lines are the averages and the dashed lines indicate the maximum and minimum possible q* from the heat flow data in this region.

Temperatures as a function of depth were calculated using the exponential heat production model of Lachenbruch (1968, 1970)

$$T = \frac{A_o D^2}{K} \quad (1-e)^{-Z/D} \quad + \quad \frac{q^* Z}{K} \qquad (8)$$

where T is the temperature.

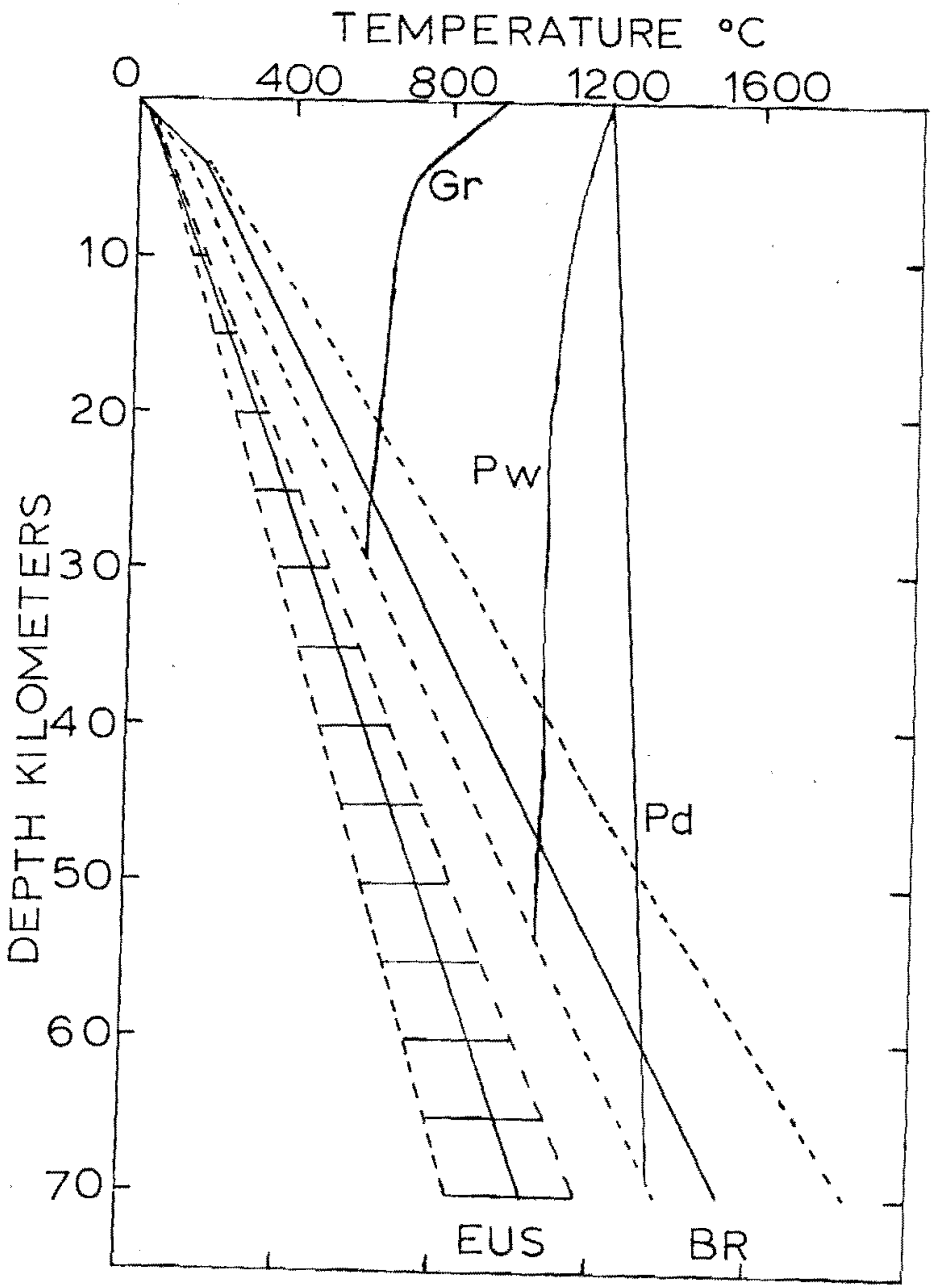
A_o is the measured basement heat production.

K is the thermal conductivity assumed to be 6.0×10^{-3} cal/cm sec °C for all curves but only below the sediments (3.5 km in BR and 1.5 km in EUS).

q* is the reduced heat flow.

In the region of EUS, q* is 0.84 HFU for the solid line, 0.68 HFU for the lower dashed line and 0.93 HFU for the upper EUS dashed

Fig. 13. Extrapolated Temperature and Petrologic Relations as a Function of Depth. Temperature plotted against depth for calculation of observed higher than normal heat flow values averaged west of 103° W (BR) and averages of heat flow data from 100° W to just west of 103° W (solid lines). Dashed lines are the same calculation for the highest and lowest heat flow values in the same respective regions. GR is the solidus for grandoiorite in the presence of excess water. Pw is the solidus for peridotite in the presence of excess water. Pd is the solidus for dry peridotite.


TEMPERATURE °C
0
400
800
1200
1600
DEPTH KILOMETERS
10
20
30
40
50
60
70
Gr
Pw
Pd
EUS
BR

line of Figure 13. All these lines were calculated using the south-central North Dakota value of heat production (A_o) or 2.7 x 10^{-13} cal/cm^3 sec.

In the region of BR, q* is 1.21 HFU for the solid line, 1.08 HFU for the lower BR dashed line and 1.47 for the upper BR dashed line. All these lines were calculated using the southwestern North Dakota heat production value (A_o) or 4.3 x 10^{-13} cal/cm^3 sec.

The solid lines labelled GR, Pw, and Pd are experimentally determined solidus curves which indicate data for granodiorite and peridotite in the presence of excess water and dry peridotite respectively. All three are from the data of Lambert and Wyllie (1972). Intersections of these curves with the temperature curves indicate depths below which rocks would be at least partially molten. The important point is that if the heat flow values west of the 1.5 HFU boundary are representative for the biotite granodiorite found in the basement there (see Table 3 and Figure 9) and if the crust is composed of granodiorite to 25 km then a zone of partial melt would be present below depths of 20 to 30 km. The Pw curve suggests similar melting relations for likely mantle rocks at depths of 40 to 50 km and these depths are approximately the thickness of the crust or the depth to the Moho from the seismic refraction data (Figure 12).

The dry peridotite curve is important because it shows that if peridotite is a major mantle constituent beneath this region it must be, even if dry, at least partially molten at depths greater than 50 to 70 kilometers suggesting the presence of a partial melt zone.

The heat flow results presented here for southwestern North Dakota are in many ways similar to those of Decker and Smithson (1975) for the Rio Grande graben. The depth to melting here is a few kilometers greater. The presence of anomalous electrical conductivity might be taken as additional evidence of partial melting (Shankland and Waff, 1977).

The heat source responsible for this phenomena must be in the lower crust or upper mantle because of the narrow transition observed between heat flow provinces (28 km).

The conclusions from the data presented in this report are:

1. There is a major heat flow province transition which occurs west of 103° W in North Dakota. West of the transition no value of heat flow is less than 1.5 HFU; east of the transition no heat flow value is less than 0.9 HFU. West of the transition temperature-depth calculations suggest the presence of a partial melt zone which acts as a heat source beginning in the lower crust or upper mantle.

2. There is good areal coincidence between the Basin and Range type of heat flow values reported here and the area of anomalous electrical conductivity reported by Alabi and others (1975). The transition between the two provinces is better chosen by the heat flow data.

3. The other available geophysical data would seem to support the interpretation of a simple northward extension of the zone of higher heat flow. Without this northward extension, the other available information would lead to internally inconsistent results. If this interpretation is correct, the region of Basin and Range type of heat flow is smaller than previously thought (see Combs and Simmons, 1973; Diment and others, 1975).

4. If the pattern in the seismic epicenters is real and verified by further observation, there is more activity along the northern

portion of the region of Basin and Range type of heat flow in North Dakota. This could suggest the presence of melts rising by penetrative convection. This opens the possibility of higher heat flow in northwestern than that observed in southwestern North Dakota. The depth to melts in northwestern North Dakota may be shallower than is indicated by the calculations in Figure 13 for southwestern North Dakota. If true, this would have important consequences for the overlying sediments above the region of such melts with regard to the generation and migration of petroleum (see Momper, 1978).

RECOMMENDATIONS

Several possible research projects are suggested to further understand the nature of the crust in the regions under consideration here.

1. Further heat flow measurements should be made, especially in northwestern North Dakota, to confirm or refute the interpretations made in this report. Additional work on heat flow and heat production for the same wells should also be undertaken. It would be of interest to see if the D values of the slope and intercept q* of the lines are similar to the two types of heat flow provinces used here.

2. Additional microseismic data should be collected either by remaining in annual contact with the LASA contractors or by placing an array of portable seismometers in northwestern North Dakota across the transition of the two provinces. Epicenters and hypocenters should be examined for evidence of rising melts.

3. A study of leveling data, if any is available, for this region should be undertaken to see if differential uplift is occurring.

4. From a geologic and geophysical standpoint questions such as what is the origin of such a feature and how long a time is required for it to form are fundamental for its understanding. Geologic maps of this region suggest that the North Dakota badlands are mostly within the high heat flow region. North south erosional edges of the Sentinel

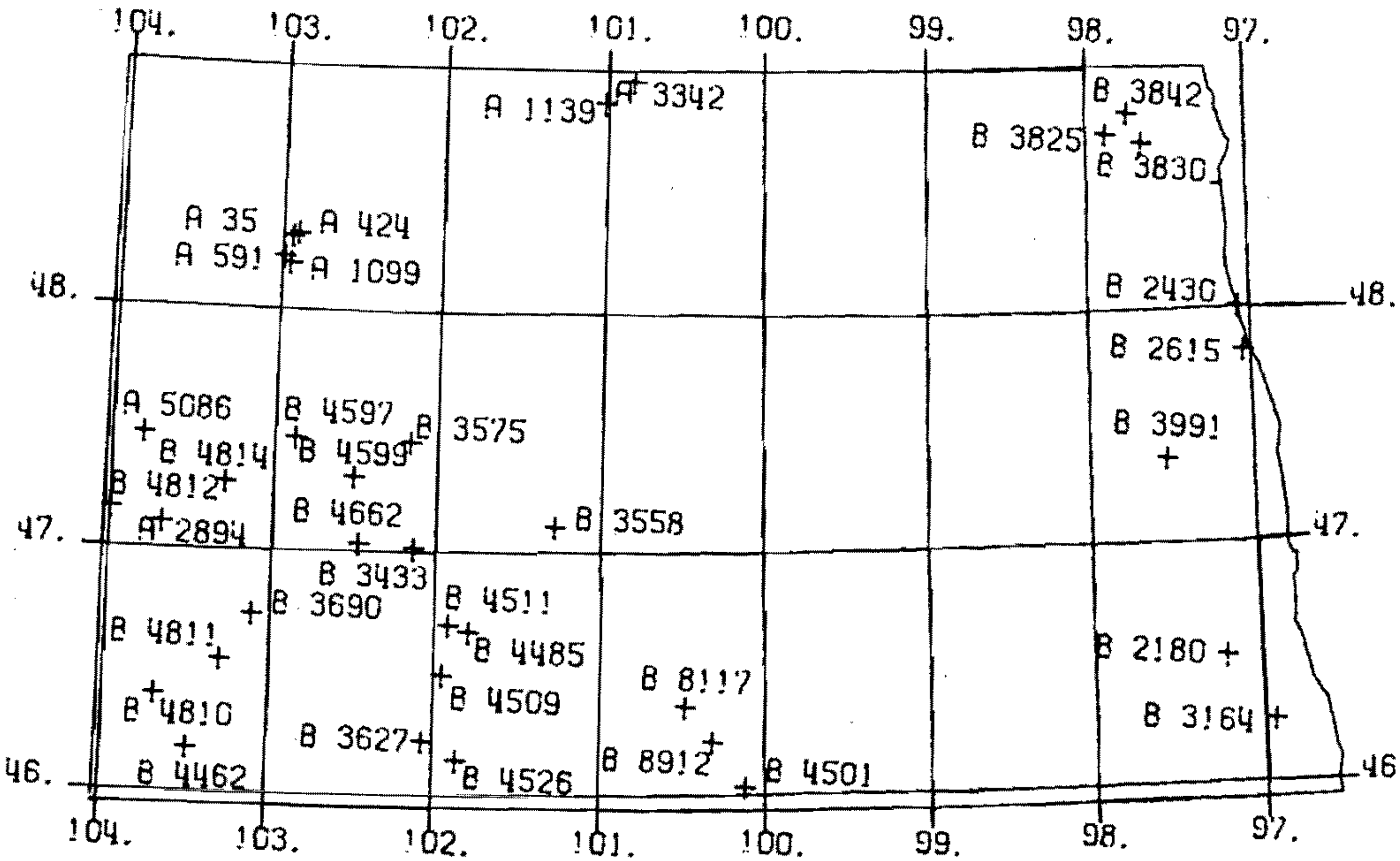
Butte, Tongue River and Tullock - Ludlow Formations in southwestern North Dakota will be of interest (see maps of Bluemle, 1977; Carlson, 1969).

5. Deep electrical sounding of this feature along the heat flow determined boundary should be undertaken to confirm or refute the interpretations made here.

APPENDIX A

DETAILS OF HEAT FLOW CALCULATIONS

Fig. 14. Well Location Map. A is NDGS; B is NDSWC.


104.
103.
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97.
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46.
A 1139
A 3342
B 3842
B 3825
B 3830
A 35
A 424
A 591
A 1099
B 2430
B 2615
A 5086
B 4597
B 3575
B 4814
B 4599
B 3991
B 4812
B 4662
B 3558
A 2894
B 3433
B 4511
B 3690
B 4811
B 4485
B 2180
B 8117
B 4810
B 4509
B 3164
B 3627
B 8912
B 4526
B 4501
B 4462

This appendix lists the temperature depth data. The user is cautioned not to use the data from the plots but to use the numerical data. The plots were intended for visual purposes only.

On the printed sheets, the number at the upper left is the well number. The next line is the land office location data in reverse order. The third line is the longitude and latitude of the well site. Line two and three are the same data in different form. Line four is the Greenwich mean time which the temperature log began and each measurement of temperature took 5 minutes. The next three lines contain data concerning the drilling of the well. The drilling period is calculated from this data and is quite probable in error ± 5 or even ± 10 days. The parameter of importance is the number of days since the first drilling period elapsed. All of them are quite large and ± 10 day uncertainty is then relatively unimportant. Casing size is inside diameter and elevation is self explanatory.

The reader is cautioned to obtain copies of the part II data reports for information about depth to water level in the water wells. All zero meter temperatures were measured in air except NDGS 5086. The user is cautioned to use near surface (less than 40 meters) data carefully because of weathering uncertainties, hydrologic uncertainties and the effect of the annual surface temperature wave.

Thermal conductivities were measured on fragments and were averaged in the interval. Interval heat flow averages are reported three lines from the last line of any calculation followed by ± standard error value. The standard deviation which allows calculation of the standard error is also reported, and method #2 flux (heat flow as used in text). The number of thermal conductivity measurements upon which the heat flow value is based is given and the upper and lower depths whose corresponding temperatures were used in this calculation.

The first plot shows all of the temperatures as a function of depth. The well number and date of log are also shown. The next plot is a plot of temperatures vs. depth which went into the method #2 calculation and these were chosen so as to incorporate all of the intervals used to compute interval flux. This plot also shows the well number. The next plots contain the thermal gradient with log date, the thermal conductivity and the heat flow all plotted as a function of the same depth scale for the intervals involved in the heat flow calculation. The average of the interval values is also reported along with the standard error. Again, users are warned not to use the plotted data but to use the listed temperatures in the pages preceding the plots.

NDSWC 4501 USGS OBSERVATION WATER WELL
EMMONS COUNTY 130N 75W SECTION 31 DCCI
46 1' 44" NORTH LATITUDE 100 7' 2" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=13.54 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
7 26 1977	11 17 1972	11 16 1972	11 17 1972

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 1711
CASING SIZE 5.08CM ELEVATION 551.38 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	11175.00	0.0	21.92	
				-666.89
50.00	16975.00	15.24	11.76	
				-263.94
100.00	20230.00	30.48	7.73	
				38.16
150.00	19715.00	45.72	8.31	
				26.77
200.00	19363.00	60.96	8.72	
				34.73
231.00	19085.00	70.41	9.05	
				12.39
250.00	19025.00	76.20	9.12	
				23.65
275.00	18875.00	83.82	9.30	
				35.98
300.00	18649.00	91.44	9.58	
				34.12
320.00	18480.00	97.54	9.78	
				38.73
340.00	18290.00	103.63	10.02	
				26.75
360.00	18160.00	109.73	10.18	
				24.95
380.00	18040.00	115.82	10.34	

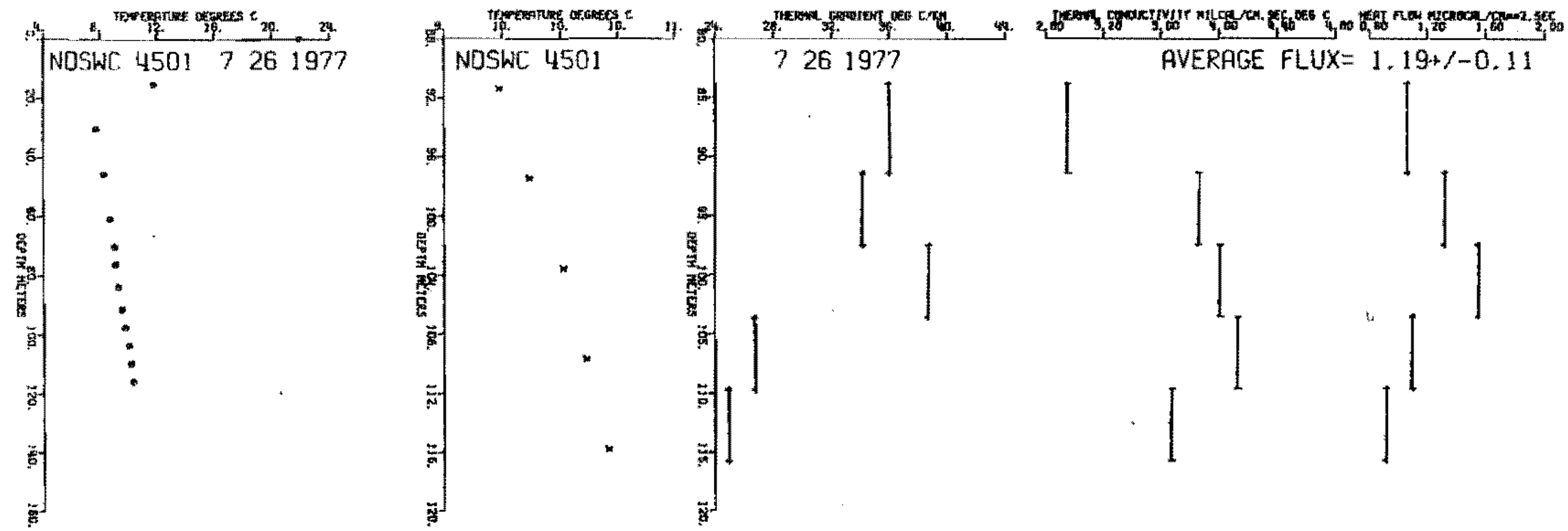
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
85.34	86.87	2.95	1.00	0.34
92.96	94.49	3.86	1.00	0.26
99.06	100.58	3.58	1.00	0.28
102.11	103.63	4.43	1.00	0.23
105.16	106.68	4.13	1.00	0.24
109.73	111.25	3.49	1.00	0.29
112.78	114.30	3.86	1.00	0.26

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
83.82	91.44	2.95	35.98	1.06
91.44	97.54	3.86	34.12	1.32
97.54	103.63	4.00	38.73	1.55
103.63	109.73	4.13	26.75	1.10
109.73	115.82	3.67	24.95	0.92

AVERAGE HEAT FLUX= 1.19 +/- 0.11 H.F.U. STD DEV 0.247

METHOD #2 FLUX= 1.20 H.F.U. # OF CONDUCTIVITIES= 7.0
UPPER DEPTH 83.82 LOWER DEPTH 115.82 METERS


NDSWC 4501 7 26 1977
TEMPERATURE DEGREES C
DEPTH METERS
NDSWC 4501
TEMPERATURE DEGREES C
DEPTH METERS
7 26 1977
THERMAL GRADIENT DEG C/KM
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.19+/-0.11

NDSWC 4526 USGS OBSERVATION WATER WELL
GRANT COUNTY 131N 89W SECTION 30 AAA
46 8' 45" NORTH LATITUDE 101 51' 20" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=14.52 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
6 19 1976	6 5 1973	6 4 1973	6 5 1973

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 1109
CASING SIZE 5.08CM ELEVATION 730.00 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	15620.00	0.0	13.74	
				-244.69
50.00	18300.00	15.24	10.01	
				-53.52
100.00	18966.00	30.48	9.19	
				3.72
150.00	18919.00	45.72	9.25	
				20.44
200.00	18662.00	60.96	9.56	
				18.66
250.00	18431.00	76.20	9.85	
				23.71
300.00	18142.00	91.44	10.21	
				31.86
345.00	17800.00	105.16	10.64	
				94.75
352.00	17644.00	107.29	10.85	
				29.04
356.00	17617.00	108.51	10.88	
				33.00
395.00	17325.00	120.40	11.27	
				67.12
400.00	17250.00	121.92	11.38	
				27.87
405.00	17219.00	123.44	11.42	
				23.65
445.00	17010.00	135.64	11.71	
				47.58
450.00	16958.00	137.16	11.78	
				42.29
455.00	16912.00	138.68	11.84	
				20.55
495.00	16734.00	150.88	12.09	
				55.11
500.00	16675.00	152.40	12.18	
				42.72
506.00	16620.00	154.23	12.26	
				34.98
545.00	16332.00	166.12	12.67	
				29.64
557.00	16258.00	169.77	12.78	
				27.91
595.00	16039.00	181.36	13.10	
				25.36
601.00	16008.00	183.18	13.15	
				26.83
605.00	15986.00	184.40	13.18	
				21.73
645.00	15810.00	196.60	13.45	
				54.79
650.00	15755.00	198.12	13.53	
				23.07
655.00	15732.00	199.64	13.57	
				19.70
695.00	15575.00	211.84	13.81	
				38.13

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
705.00	15500.00	214.88	13.92	
				17.86
745.00	15360.00	227.08	14.14	
				92.91
750.00	15270.00	228.60	14.28	
				67.12
755.00	15205.00	230.12	14.38	
				-58.79
760.00	15262.00	231.65	14.29	
				25.83
796.00	15082.00	242.62	14.58	
				20.83
810.00	15026.00	246.89	14.67	
				19.51
821.00	14985.00	250.24	14.73	

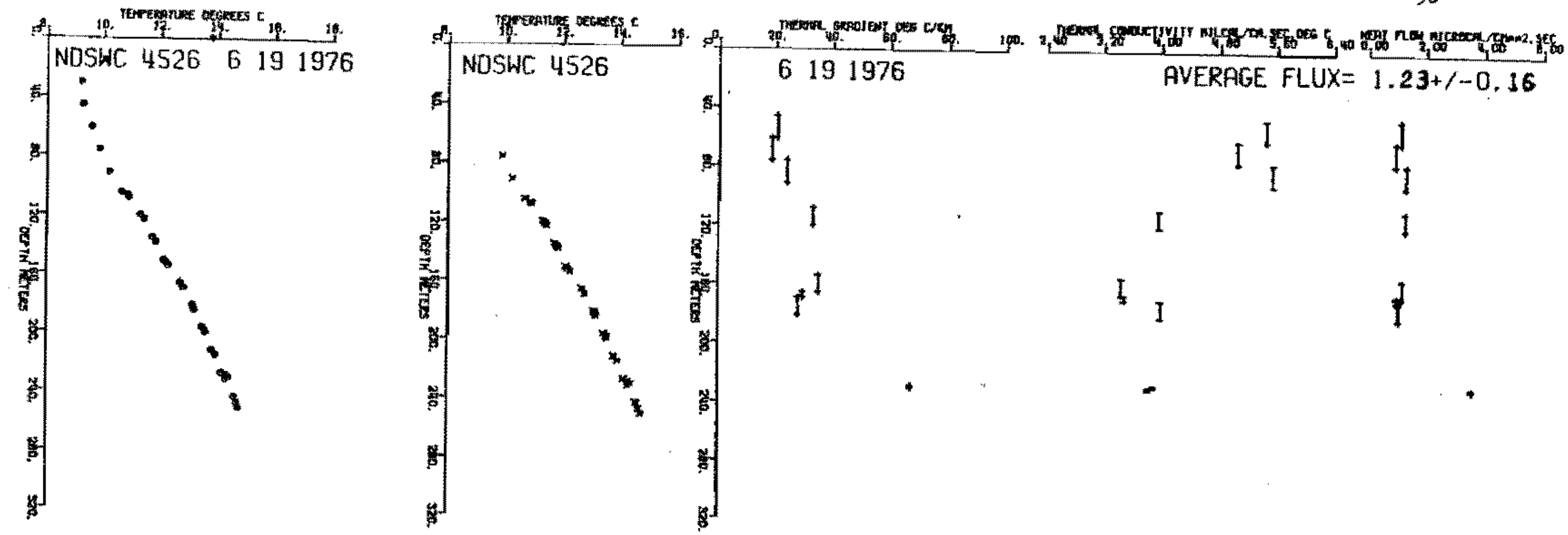
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
59.43	60.96	5.44	1.00	0.18
65.53	67.05	4.67	1.00	0.21
70.10	71.63	3.32	1.00	0.30
74.68	76.20	7.17	1.00	0.14
79.25	80.77	4.36	1.00	0.23
83.82	85.34	4.73	1.00	0.21
88.39	89.92	7.56	1.00	0.13
108.20	109.73	4.10	1.00	0.24
111.25	112.78	3.62	1.00	0.28
114.30	115.82	4.23	1.00	0.24
155.45	156.97	3.40	1.00	0.29
158.50	160.02	3.52	1.00	0.28
166.12	167.64	3.46	1.00	0.29
167.64	169.16	3.53	1.00	0.28
170.69	172.21	3.93	1.00	0.25
173.73	175.26	4.08	1.00	0.25
227.07	228.60	3.91	1.00	0.26
228.60	230.00	3.84	1.00	0.26

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
45.72	60.96	5.44	20.44	1.11
60.96	76.20	3.99	18.66	0.75
76.20	91.44	5.55	23.71	1.32
107.29	108.51	4.10	29.04	1.19
108.51	120.40	3.92	33.00	1.30
154.23	166.12	3.46	34.98	1.21
166.12	169.77	3.49	29.64	1.04
169.77	181.36	4.00	27.91	1.12
214.88	227.08	3.91	17.86	0.70
228.60	230.12	3.84	67.12	2.58

AVERAGE HEAT FLUX= 1.23 +/- 0.16 H.F.U. STD DEV 0.518

METHOD #2 FLUX= 1.17 H.F.U. # OF CONDUCTIVITIES=17.0
UPPER DEPTH 60.96 LOWER DEPTH 230.12 METERS


TEMPERATURE DEGREES C
NDSWC 4526 6 19 1976
DEPTH METERS
TEMPERATURE DEGREES C
NDSWC 4526
DEPTH METERS
THERMAL GRADIENT DEG C/KM
6 19 1976
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.23+/-0.16

NDSWC 4526 USGS OBSERVATION WATER WELL
GRANT COUNTY 131N 89W SECTION 30 AAA
46 8' 45" NORTH LATITUDE 101 51' 20" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=17.11 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
10 5 1976	6 5 1973	6 4 1973	6 5 1973

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 1217
CASING SIZE 5.08CM ELEVATION 73.00 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	19650.00	0.0	8.39	
50.00	18740.00	15.24	9.47	70.65
100.00	18700.00	30.48	9.51	3.19
150.00	18570.00	45.72	9.67	10.44
200.00	18240.00	60.96	10.08	26.88
250.00	17985.00	76.20	10.41	21.18
300.00	17805.00	91.44	10.64	15.15
351.00	17340.00	106.98	11.25	39.63
400.00	17225.00	121.92	11.41	10.51
450.00	16875.00	137.16	11.90	31.83
500.00	16540.00	152.40	12.37	31.24
551.00	16220.00	167.94	12.84	29.90
602.00	15840.00	183.49	13.40	36.44
650.00	15655.00	198.12	13.68	19.21
700.00	15390.00	213.36	14.09	26.91
750.00	15125.00	228.60	14.51	27.35
761.00	15110.00	231.95	14.53	7.06
781.00	15000.00	238.05	14.71	28.68
792.00	14935.00	241.40	14.81	30.87

NDSWC 4526 USGS OBSERVATION WATER WELL

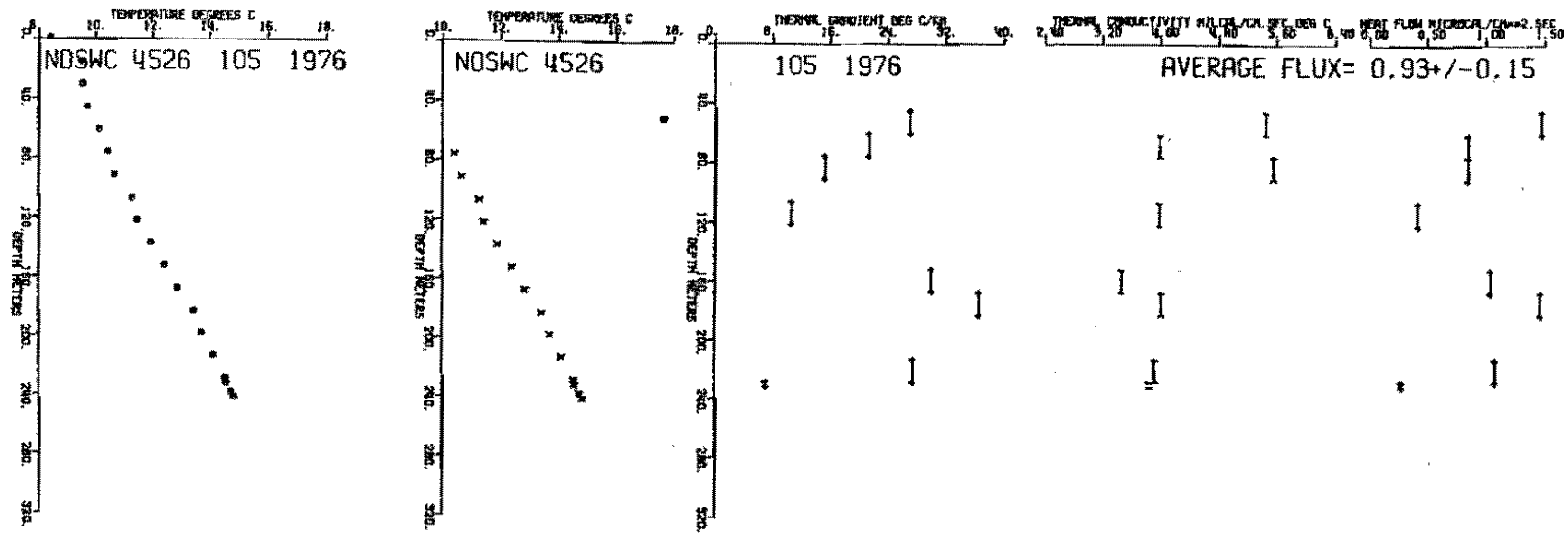
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
59.43	60.96	5.44	1.00	0.18
65.53	67.05	4.67	1.00	0.21
70.10	71.63	3.32	1.00	0.30
74.68	76.20	7.17	1.00	0.14
79.25	80.77	4.36	1.00	0.23
83.82	85.34	4.73	1.00	0.21
88.39	89.92	7.56	1.00	0.13
108.20	109.73	4.10	1.00	0.24
111.25	112.78	3.62	1.00	0.28
114.30	115.82	4.23	1.00	0.24
155.45	156.97	3.40	1.00	0.29
158.50	160.02	3.52	1.00	0.28
166.12	167.64	3.46	1.00	0.29
167.64	169.16	3.53	1.00	0.28
170.69	172.21	3.93	1.00	0.25
173.73	175.26	4.08	1.00	0.25
227.07	228.60	3.91	1.00	0.26
228.60	230.00	3.84	1.00	0.26

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
45.72	60.96	5.44	26.88	1.46
60.96	76.20	3.99	21.18	0.85
76.20	91.44	5.55	15.15	0.84
106.98	121.92	3.98	10.51	0.42
152.40	167.94	3.46	29.90	1.03
167.94	183.49	4.00	36.44	1.46
213.36	228.60	3.91	27.35	1.07
228.60	231.95	3.84	7.06	0.27

AVERAGE HEAT FLUX= 0.93 +/- 0.15 H.F.U. STD DEV 0.432

METHOD #2 FLUX= 1.07 H.F.U. # OF CONDUCTIVITIES=17.0
UPPER DEPTH 60.96 LOWER DEPTH 231.95 METERS


TEMPERATURE DEGREES C
NOSWC 4526 105 1976
DEPTH METERS
TEMPERATURE DEGREES C
NOSWC 4526
THERMAL GRADIENT DEG C/KM
105 1976
THERMAL CONDUCTIVITY M/CAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 0.93+/-0.15

NDSWC 4462 USGS OBSERVATION WATER WELL
BOWMAN COUNTY 131N 102W SECTION 07 DDD1
46 10' 34'' NORTH LATITUDE 103 28' 28'' WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=17.36 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
8 15 1975	7 30 1972	7 15 1972	7 30 1972

DRILLING PERIOD= 15 DAYS DAYS SINCE 1ST PERIOD= 1111
CASING SIZE 5.08CM ELEVATION 897.64 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	13830.00	0.0	16.66	
				-411.85
50.00	18000.00	15.24	10.39	
				-49.23
100.00	18600.00	30.48	9.64	
				-15.20
150.00	18790.00	45.72	9.40	
				5.99
200.00	18715.00	60.96	9.50	
				52.80
251.00	18055.00	76.50	10.32	
				63.59
300.00	17330.00	91.44	11.27	
				38.59
350.00	16904.00	106.68	11.85	
				51.44
400.00	16355.00	121.92	12.64	
				44.65
450.00	15895.00	137.16	13.32	
				44.68
500.00	15450.00	152.40	14.00	
				48.14
551.00	14975.00	167.94	14.75	
				39.49
600.00	14611.00	182.88	15.34	
				41.96
650.00	14228.00	198.12	15.98	
				28.19
700.00	13977.00	213.36	16.41	
				37.18
750.00	13654.00	228.60	16.97	
				37.04
800.00	13341.00	243.84	17.54	
				35.34
850.00	13050.00	259.08	18.08	
				36.40
900.00	12758.00	274.32	18.63	
				30.68
950.00	12518.00	289.56	19.10	
				19.42
970.00	12458.00	295.66	19.22	

NDSWC 4462 USGS OBSERVATION WATER WELL

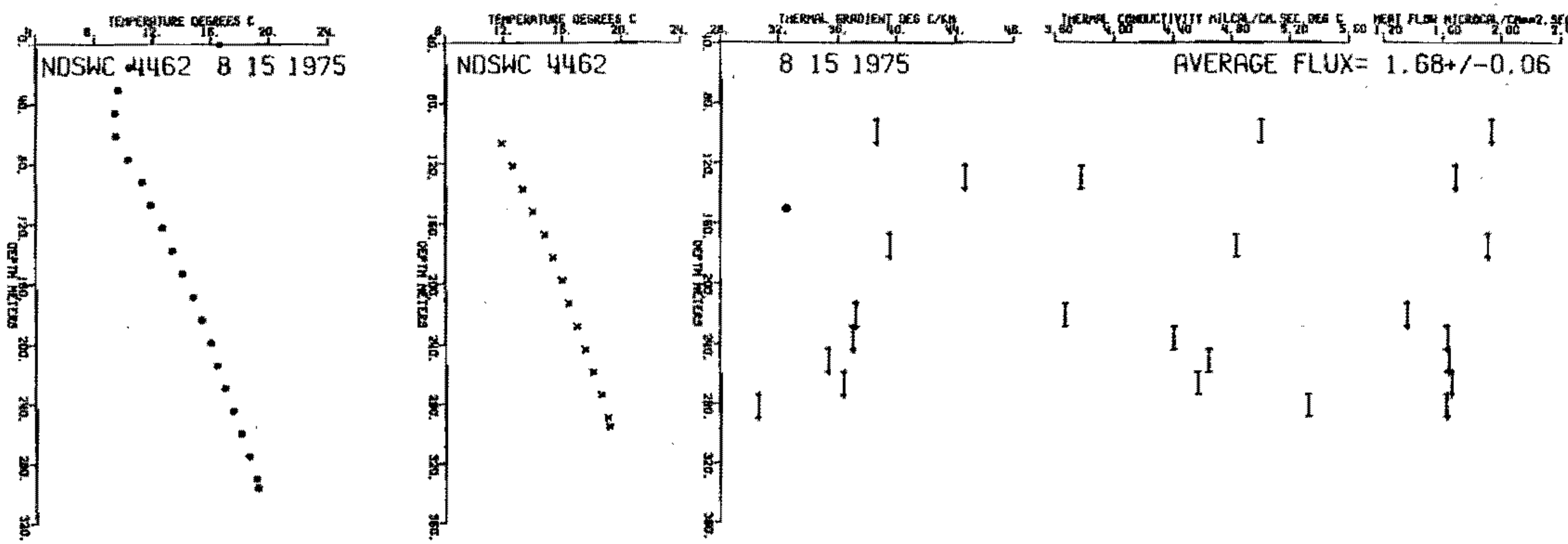
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
99.06	100.58	5.00	3.00	0.20
124.97	126.49	3.78	2.00	0.26
169.16	170.68	4.84	2.00	0.21
214.88	216.41	3.10	1.00	0.32
217.90	219.45	4.08	1.00	0.25
219.46	220.98	3.76	2.00	0.27
231.65	233.17	3.89	3.00	0.26
236.22	237.74	5.51	1.00	0.18
237.74	239.27	5.32	1.00	0.19
240.79	242.32	3.96	1.00	0.25
243.84	245.36	4.11	1.00	0.24
249.94	251.46	5.82	1.00	0.17
257.56	259.00	4.03	1.00	0.25
259.08	260.60	4.45	1.00	0.22
260.60	262.13	5.27	2.00	0.19
262.13	263.65	3.77	1.00	0.27
263.65	265.18	3.63	1.00	0.28
265.18	266.70	3.82	1.00	0.26
269.75	271.27	5.81	1.00	0.17
274.32	275.84	4.13	1.00	0.24
275.84	277.37	8.12	1.00	0.12
277.00	278.89	3.78	1.00	0.26
283.46	284.99	5.31	1.00	0.19

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
91.44	106.68	5.00	38.59	1.93
121.92	137.16	3.78	44.65	1.69
167.94	182.88	4.84	39.49	1.91
213.36	228.60	3.67	37.18	1.37
228.60	243.84	4.41	37.04	1.63
243.84	259.08	4.65	35.34	1.64
259.08	274.32	4.57	36.40	1.66
274.32	289.56	5.33	30.68	1.64

AVERAGE HEAT FLUX= 1.68 +/- 0.06 H.F.U. STD DEV 0.177

METHOD #2 FLUX= 1.73 H.F.U. # OF CONDUCTIVITIES=31.0
UPPER DEPTH 91.44 LOWER DEPTH 289.56 METERS


NDSWC 4462 8 15 1975
TEMPERATURE DEGREES C
DEPTH METERS
NDSWC 4462
TEMPERATURE DEGREES C
DEPTH METERS
8 15 1975
THERMAL GRADIENT DEG C/KM
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.68+/-0.06

NDSWC 4462S USGS OBSERVATION WATER WELL
BOWMAN COUNTY 131N 102W SECTION 07 DDD3
46 10' 34'' NORTH LATITUDE 103 28' 28'' WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG= 7.32 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
8 15 1975	7 30 1972	7 15 1972	7 30 1972

DRILLING PERIOD= 15 DAYS DAYS SINCE 1ST PERIOD= 1111
CASING SIZE 5.08CM ELEVATION 897.64 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	9510.00	0.0	26.02	
				-633.08
50.00	14000.00	15.24	16.37	
				-195.57
100.00	15850.00	30.48	13.39	
				-100.19
150.00	16900.00	45.72	11.86	
				-149.51
200.00	18645.00	60.96	9.58	
				48.68
250.00	18050.00	76.20	10.32	
				53.09
300.00	17429.00	91.44	11.13	
				39.49
350.00	16990.00	106.68	11.73	
				51.81
400.00	16434.00	121.92	12.52	
				47.31
451.00	15935.00	137.46	13.26	
				44.41
500.00	15500.00	152.40	13.92	
				49.60
552.00	15000.00	168.25	14.71	
				38.07
601.00	14648.00	183.18	15.28	
				30.40
639.00	14435.00	194.77	15.63	

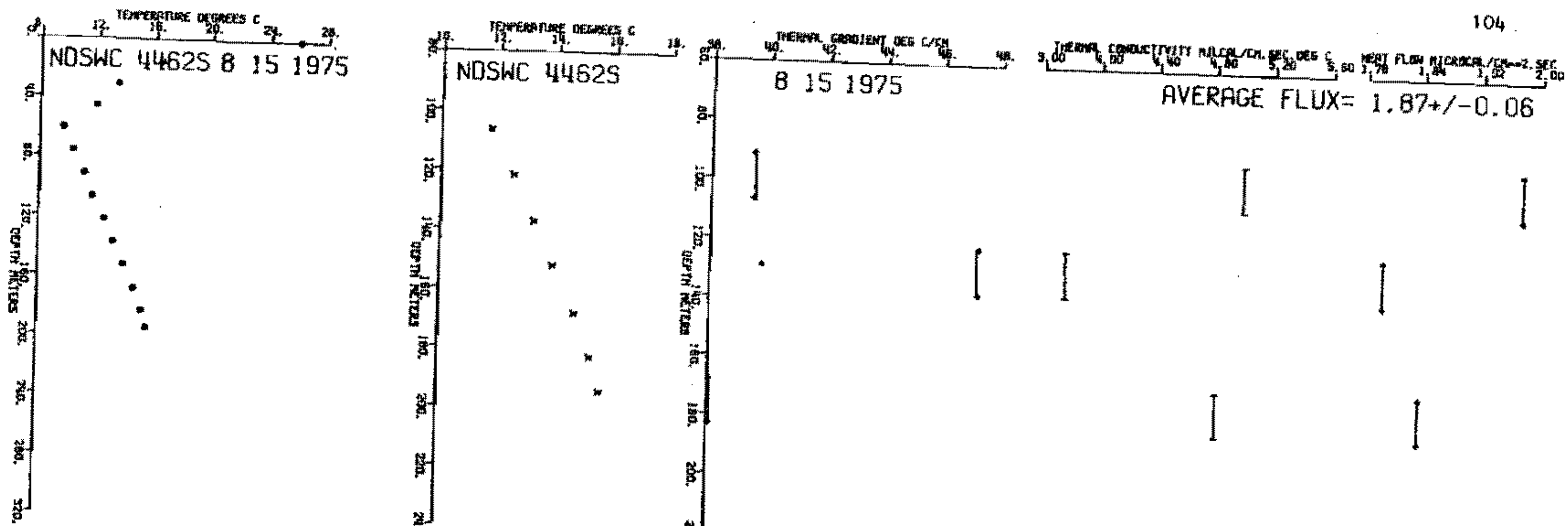
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
99.06	100.58	5.01	3.00	0.20
124.96	126.49	3.78	2.00	0.26
169.16	170.68	4.84	2.00	0.21

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
91.44	106.68	5.01	39.49	1.98
121.92	137.46	3.78	47.31	1.79
168.25	183.18	4.84	38.07	1.84

AVERAGE HEAT FLUX= 1.87 +/- 0.06 H.F.U. STD DEV 0.098

METHOD #2 FLUX= 2.05 H.F.U. # OF CONDUCTIVITIES= 7.0
UPPER DEPTH 91.44 LOWER DEPTH 183.18 METERS


NDSWC 4462S 8 15 1975
TEMPERATURE DEGREES C
DEPTH METERS
NDSWC 4462S
TEMPERATURE DEGREES C
DEPTH METERS
8 15 1975
THERMAL GRADIENT DEG C/CM
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.87+/-0.06

NDSWC 8912 USGS OBSERVATION WATER WELL
EMMONS COUNTY 132N 77W SECTION 04 CBC
46 13' 52" NORTH LATITUDE 100 18' 53" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=13.50 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
7 27 1977	9 18 1971	9 17 1971	9 18 1971

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 2137
CASING SIZE 2.54CM ELEVATION 510.54 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	12575.00	0.0	18.99	
				-365.47
50.00	15830.00	15.24	13.42	
				-281.43
100.00	19020.00	30.48	9.13	
				7.47
150.00	18925.00	45.72	9.24	
				22.97
175.00	18780.00	53.34	9.42	
				20.79
200.00	18650.00	60.96	9.58	
				38.45
221.00	18450.00	67.36	9.82	
				53.88
240.00	18200.00	73.15	10.13	
				17.77
261.00	18110.00	79.55	10.25	
				13.15
280.00	18050.00	85.34	10.32	
				10.37
300.00	18000.00	91.44	10.39	
				13.94
310.00	17967.00	94.49	10.43	
				35.64
320.00	17882.00	97.54	10.54	
				49.90
330.00	17764.00	100.58	10.69	
				45.39
336.00	17700.00	102.41	10.77	

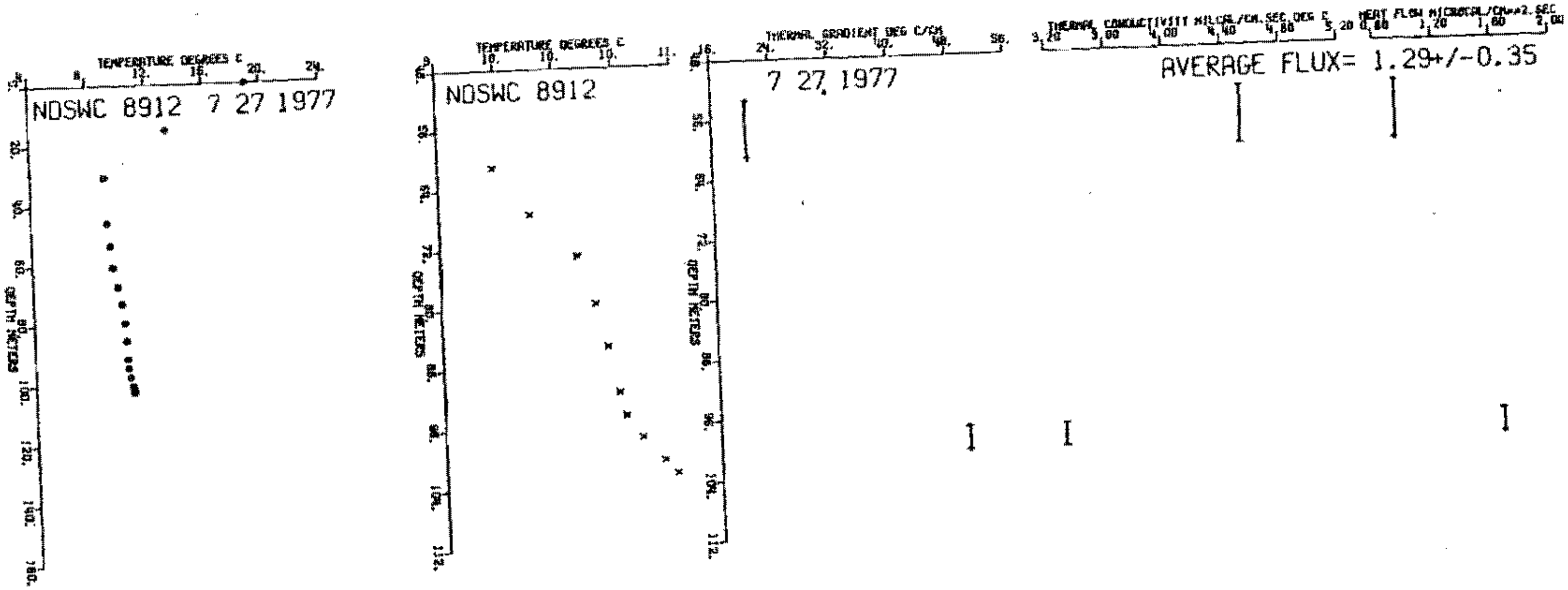
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
54.86	56.38	4.11	1.00	0.24
57.91	59.44	5.13	1.00	0.19
59.44	60.96	4.34	1.00	0.23
97.54	99.06	3.28	1.00	0.30
100.58	102.12	3.40	1.00	0.29

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
53.34	60.96	4.53	20.79	0.94
97.54	100.58	3.28	49.90	1.64

AVERAGE HEAT FLUX= 1.29 +/- 0.35 H.F.U. STD DEV 0.492

METHOD #2 FLUX= 1.09 H.F.U. # OF CONDUCTIVITIES= 5.0
UPPER DEPTH 53.34 LOWER DEPTH 102.41 METERS



TEMPERATURE DEGREES C
NDSWC 8912 7 27 1977
DEPTH METERS
TEMPERATURE DEGREES C
NDSWC 8912
DEPTH METERS
THERMAL GRADIENT DEG C/CM
7 27 1977
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.29+/-0.35

NDSWC 3627 USGS OBSERVATION WATER WELL
HETTINGER COUNTY 132N 91W SECTION 28 DDD
46 13' 15" NORTH LATITUDE 102 3' 45" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=17.16 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
7 26 1975	8 20 1968	8 19 1968	8 20 1968

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 2530
CASING SIZE 10.16CM ELEVATION 752.55 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	9200.00	0.0	26.86	
				-776.35
50.00	14800.00	15.24	15.03	
				-287.79
100.00	17800.00	30.48	10.64	
				-41.68
150.00	18300.00	45.72	10.01	
				-19.54
200.00	18540.00	60.96	9.71	
				131.91
250.00	17000.00	76.20	11.72	
				-130.61
300.00	18524.00	91.44	9.73	
				26.60
358.00	18147.00	109.12	10.20	
				31.79
400.00	17828.00	121.92	10.61	
				31.25
450.00	17465.00	137.16	11.08	
				29.02
501.00	17134.00	152.70	11.53	
				26.96
550.00	16845.00	167.64	11.94	
				29.38
600.00	16530.00	182.88	12.39	
				30.05
650.00	16215.00	198.12	12.84	
				34.19
700.00	15865.00	213.36	13.36	
				31.35
750.00	15552.00	228.60	13.84	
				37.13
800.00	15190.00	243.84	14.41	
				26.66
850.00	14934.00	259.08	14.81	
				26.53
900.00	14684.00	274.32	15.22	
				24.32
950.50	14457.00	289.71	15.59	
				25.83
1000.00	14225.00	304.80	15.98	
				22.22
1050.00	14027.00	320.04	16.32	
				0.61
1087.00	14023.00	331.32	16.33	

NDSWC 3627 USGS OBSERVATION WATER WELL

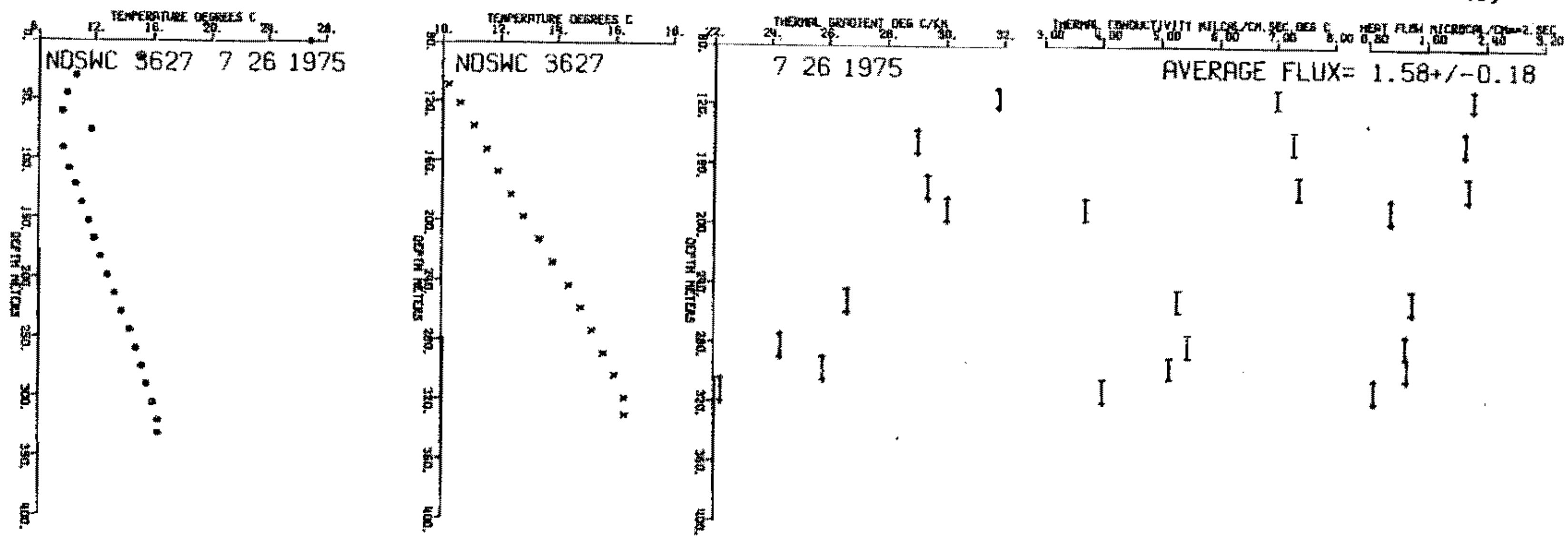
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
118.87	120.40	7.00	1.00	0.14
149.35	150.87	7.30	1.00	0.14
175.26	176.78	7.39	1.00	0.14
193.55	195.07	3.72	1.00	0.27
252.98	254.51	5.31	1.00	0.19
280.42	281.94	5.47	1.00	0.18
294.13	295.66	5.16	1.00	0.19
318.52	320.04	4.02	1.00	0.25

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
109.12	121.92	7.00	31.79	2.23
137.16	152.70	7.30	29.02	2.12
167.64	182.88	7.39	29.38	2.17
182.88	198.12	3.72	30.05	1.12
243.84	259.08	5.31	26.66	1.42
274.32	289.71	5.47	24.32	1.33
289.71	304.80	5.16	25.83	1.33
304.80	320.04	4.02	22.22	0.89

AVERAGE HEAT FLUX= 1.58 +/- 0.18 H.F.U. STD DEV 0.520

METHOD #2 FLUX= 1.54 H.F.U. # OF CONDUCTIVITIES= 8.0
UPPER DEPTH 91.44 LOWER DEPTH 320.04 METERS



TEMPERATURE DEGREES C
NOSWC 3627 7 26 1975
DEPTH METERS
TEMPERATURE DEGREES C
NOSWC 3627
DEPTH METERS
THERMAL GRADIENT DEG C/KM
7 26 1975
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.58+/-0.18

NDSWC 3164 USGS OBSERVATION WATER WELL
RICHLAND COUNTY 132N 50W SECTION 10 BCC
46 15' 45" NORTH LATITUDUE 96 56' 45" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=12.25 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
7 4 1976	8 12 1964	8 11 1964	8 12 1964

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 4341
CASING SIZE 12.70CM ELEVATION 301.75 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	8200.00	0.0	29.83	
				-2783.84
25.00	19450.00	7.62	8.62	
				7.66
50.00	19400.00	15.24	8.68	
				7.69
75.00	19350.00	22.86	8.74	
				18.49
100.00	19230.00	30.48	8.88	
				12.43
125.00	19150.00	38.10	8.97	
				20.31
150.00	19020.00	45.72	9.13	
				15.76
175.00	18920.00	53.34	9.25	
				11.02
200.00	18850.00	60.96	9.33	
				40.05
201.00	18840.00	61.26	9.34	

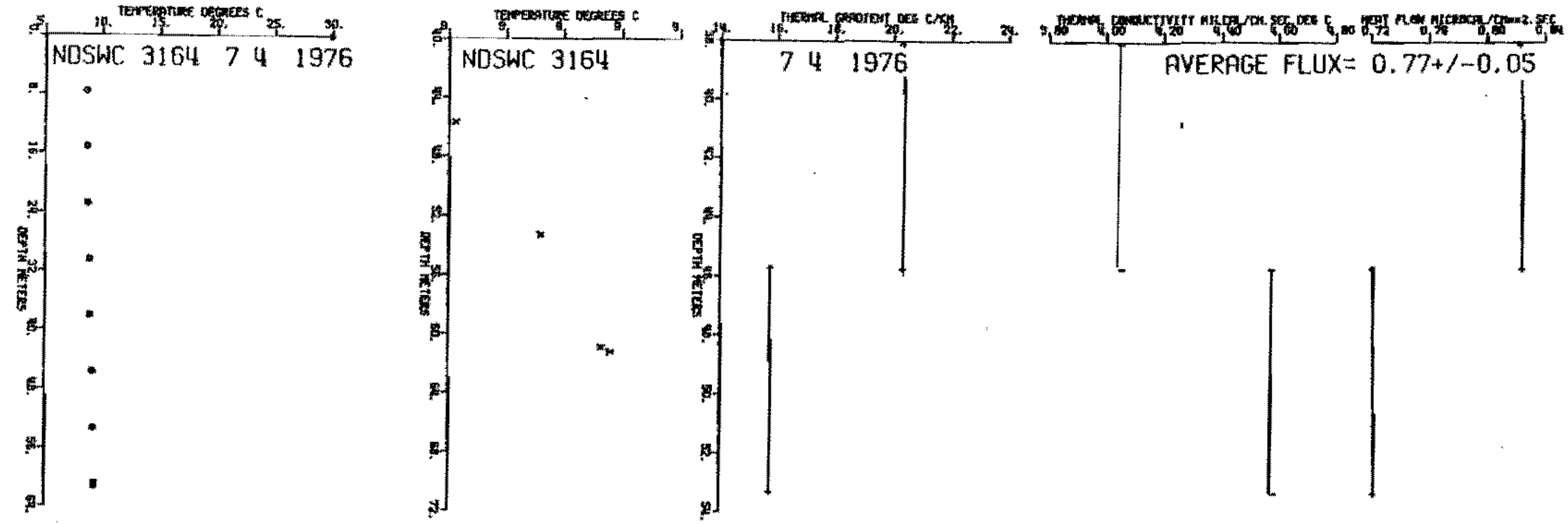
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
38.70	40.23	4.53	1.00	0.22
40.23	41.75	4.51	1.00	0.22
43.28	44.81	3.11	1.00	0.32
49.38	50.90	5.22	1.00	0.19
50.90	52.43	3.92	1.00	0.26

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
38.10	45.72	4.05	20.31	0.82
45.72	53.34	4.57	15.76	0.72

AVERAGE HEAT FLUX= 0.77 +/- 0.05 H.F.U. STD DEV 0.072

METHOD #2 FLUX= 0.74 H.F.U. # OF CONDUCTIVITIES= 5.0
UPPER DEPTH 38.10 LOWER DEPTH 53.34 METERS


TEMPERATURE DEGREES C
NDSWC 3164 7 4 1976
DEPTH METERS
TEMPERATURE DEGREES C
NDSWC 3164
DEPTH METERS
THERMAL GRADIENT DEG C/KM
7 4 1976
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 0.77+/-0.05

NDSWC 8117 USGS OBSERVATION WATER WELL
EMMONS COUNTY 133N 78W SECTION 04 CBC
46 21' 40" NORTH LATITUDE 100 30' 14" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=16.10 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
7 27 1977	9 15 1971	9 14 1971	9 15 1971

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 2140
CASING SIZE 2.54CM ELEVATION 510.54 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	11646.00	0.0	20.89	
				-838.84
50.00	19900.00	15.24	8.10	
				5.98
100.00	19820.00	30.48	8.19	
				6.73
125.00	19775.00	38.10	8.25	
				5.05
151.00	19740.00	46.02	8.29	
				16.90
180.00	19610.00	54.86	8.44	
				7.61
190.00	19590.00	57.91	8.46	
				44.86
200.00	19472.00	60.96	8.60	
				31.97
211.00	19380.00	64.31	8.70	
				22.08
218.00	19340.00	66.45	8.75	

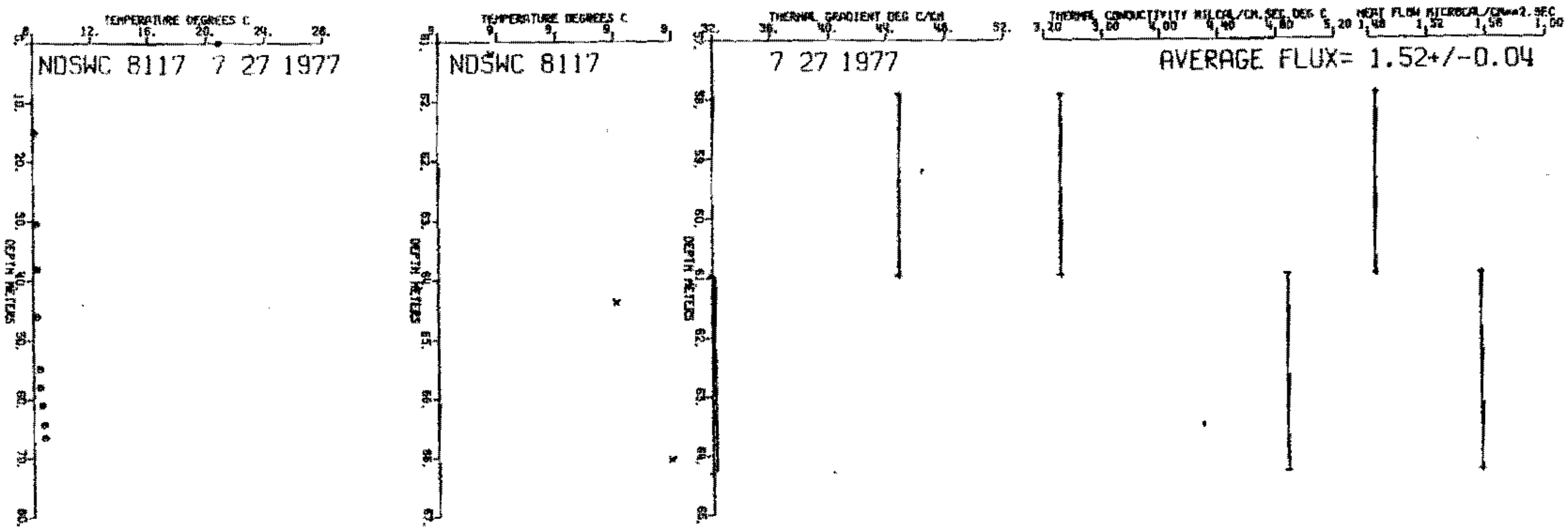
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
59.44	60.96	3.31	1.00	0.30
61.00	64.00	4.87	1.00	0.21

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
57.91	60.96	3.31	44.86	1.48
60.96	64.31	4.87	31.97	1.56

AVERAGE HEAT FLUX= 1.52 +/- 0.04 H.F.U. STD DEV 0.051

METHOD #2 FLUX= 1.50 H.F.U. # OF CONDUCTIVITIES= 2.0
UPPER DEPTH 57.91 LOWER DEPTH 64.31 METERS


TEMPERATURE DEGREES C
NDSWC 8117 7 27 1977
DEPTH METERS
TEMPERATURE DEGREES C
NDSWC 8117
DEPTH METERS
THERMAL GRADIENT DEG C/KM
7 27 1977
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.52+/-0.04

NDSWC 4810 USGS OBSERVATION WATER WELL
SLOPE COUNTY 134N 104W SECTION 24 DDD
46 23' 49'' NORTH LATITUDE 103 40' 43'' WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=22.30 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
7 3 1976	7 15 1975	7 1 1975	7 15 1975

DRILLING PERIOD= 14 DAYS DAYS SINCE 1ST PERIOD= 353
CASING SIZE 10.16CM ELEVATION 396.24 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	19580.00	0.0	8.47	
				15.25
50.00	19380.00	15.24	8.70	
				48.91
100.00	18755.00	30.48	9.45	
				25.15
152.00	18430.00	46.33	9.85	
				30.42
200.00	18075.00	60.96	10.29	
				52.69
251.00	17445.00	76.50	11.11	
				38.53
300.00	17025.00	91.44	11.69	
				32.76
350.00	16670.00	106.68	12.19	
				37.87
400.00	16270.00	121.92	12.76	
				36.52
450.00	15895.00	137.16	13.32	
				57.51
500.00	15325.00	152.40	14.20	
				33.67
550.00	15000.00	167.64	14.71	
				71.93
600.00	14330.00	182.88	15.80	
				24.65
652.00	14100.00	198.73	16.20	
				42.80
700.00	13740.00	213.36	16.82	
				38.77
750.00	13410.00	228.60	17.41	
				39.30
800.00	13085.00	243.84	18.01	
				29.14
850.00	12850.00	259.08	18.46	
				27.83
900.00	12630.00	274.32	18.88	
				33.66
950.00	12370.00	289.56	19.39	
				35.15
1000.00	12105.00	304.80	19.93	
				29.16
1050.00	11890.00	320.04	20.37	
				33.22
1100.00	11650.00	335.28	20.88	
				35.50
1150.00	11400.00	350.52	21.42	
				30.52
1200.00	11190.00	365.76	21.89	
				19.24
1250.00	11060.00	381.00	22.18	
				18.38
1301.00	10935.00	396.54	22.46	

NDSWC 4810 USGS OBSERVATION WATER WELL

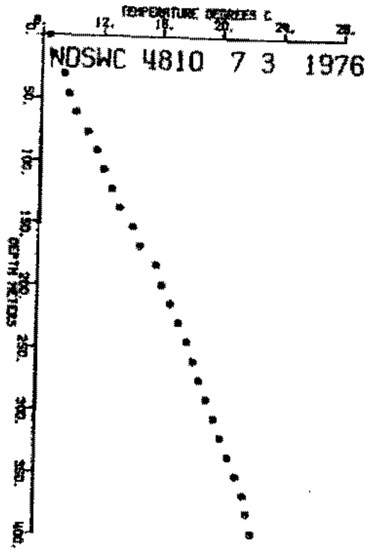
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
86.86	88.39	4.36	1.00	0.23
92.96	94.49	3.90	1.00	0.26
103.63	105.15	3.90	1.00	0.26
109.72	111.25	6.43	1.00	0.16
112.77	114.30	4.33	1.00	0.23
115.82	117.35	5.20	1.00	0.19
118.87	120.40	3.91	1.00	0.26
122.00	123.44	5.32	1.00	0.19
124.97	126.49	5.01	1.00	0.20
128.02	129.54	3.93	1.00	0.25
134.11	135.63	5.01	1.00	0.20
199.64	201.16	3.74	1.00	0.27
208.78	210.31	3.76	1.00	0.27
214.00	214.88	3.70	1.00	0.27
217.93	219.46	3.75	1.00	0.27
225.55	227.07	4.36	1.00	0.23
231.65	233.17	4.11	1.00	0.24
236.22	237.74	3.74	1.00	0.27
245.36	246.88	4.00	1.00	0.25
252.98	254.50	4.31	1.00	0.23
277.37	278.89	4.65	1.00	0.22
294.13	295.66	4.38	1.00	0.23
298.70	300.23	3.91	1.00	0.26
306.32	307.84	4.55	1.00	0.22
310.89	312.42	3.87	1.00	0.26
329.18	330.71	4.16	1.00	0.24
338.32	339.85	4.23	1.00	0.24
347.47	349.00	4.75	1.00	0.21
352.04	353.57	4.13	1.00	0.24
356.62	358.14	8.13	1.00	0.12

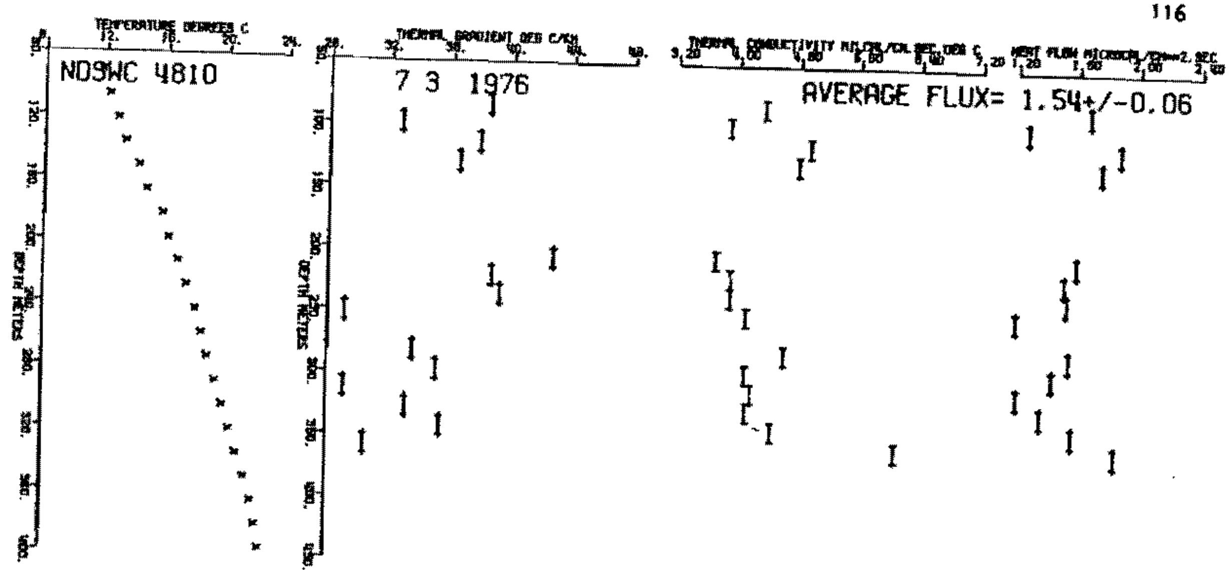
HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
76.50	91.44	4.36	38.53	1.68
91.44	106.68	3.90	32.76	1.28
106.68	121.92	4.97	37.87	1.88
121.92	137.16	4.82	36.52	1.76
198.73	213.36	3.75	42.80	1.61
213.36	228.60	3.94	38.77	1.53
228.60	243.84	3.92	39.30	1.54
243.84	259.08	4.15	29.14	1.21
274.32	289.56	4.65	33.66	1.57
289.56	304.80	4.14	35.15	1.46
304.80	320.04	4.21	29.16	1.23
320.04	335.28	4.16	33.22	1.38
335.28	350.52	4.49	35.50	1.59
350.52	365.76	6.13	30.52	1.87

AVERAGE HEAT FLUX= 1.54 +/- 0.06 H.F.U. STD DEV 0.216

METHOD #2 FLUX= 1.61 H.F.U. # OF CONDUCTIVITIES=30.0
UPPER DEPTH 76.50 LOWER DEPTH 365.76 METERS


TEMPERATURE DEGREES C
NDSWC 4810 7 3 1976
DEPTH METERS


TEMPERATURE DEGREES C
NDSWC 4810
DEPTH METERS
THERMAL GRADIENT DEG C/KM
7 3 1976
THERMAL CONDUCTIVITY
HEAT FLOW
AVERAGE FLUX= 1.54+/-0.06

NDSWC 2180 USGS OBSERVATION WATER WELL
RICHLAND COUNTY 135N 52W SECTION 10 ACA-1
46 31' 25" NORTH LATITUDE 97 12' 14" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=10.53 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
7 4 1976	9 14 1963	9 12 1963	9 13 1963

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 4674
CASING SIZE 2.54CM ELEVATION 318.52 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	7870.00	0.0	30.91	
				-3013.76
25.00	20040.00	7.62	7.95	
				147.41
50.00	19070.00	15.24	9.07	
				9.30
76.00	19008.00	23.16	9.14	
				26.53
101.00	18840.00	30.78	9.34	
				14.39
130.00	18735.00	39.62	9.47	
				19.46
150.00	18638.00	45.72	9.59	
				21.43
175.00	18505.00	53.34	9.75	
				23.61
200.00	18360.00	60.96	9.93	
				21.44
221.00	18250.00	67.36	10.07	
				2.84
250.00	18230.00	76.20	10.10	
				10.01
252.00	18225.00	76.81	10.10	

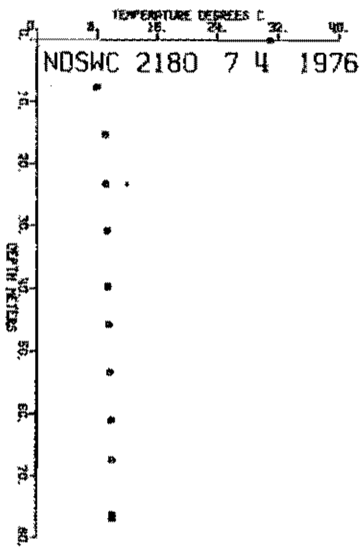
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
40.01	41.60	4.50	1.00	0.22
57.61	59.21	2.74	1.00	0.36
64.01	65.61	3.48	1.00	0.29

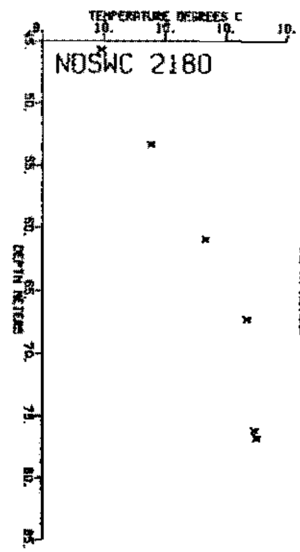
HEAT FLUX CALCULATION INTERVAL METHOD

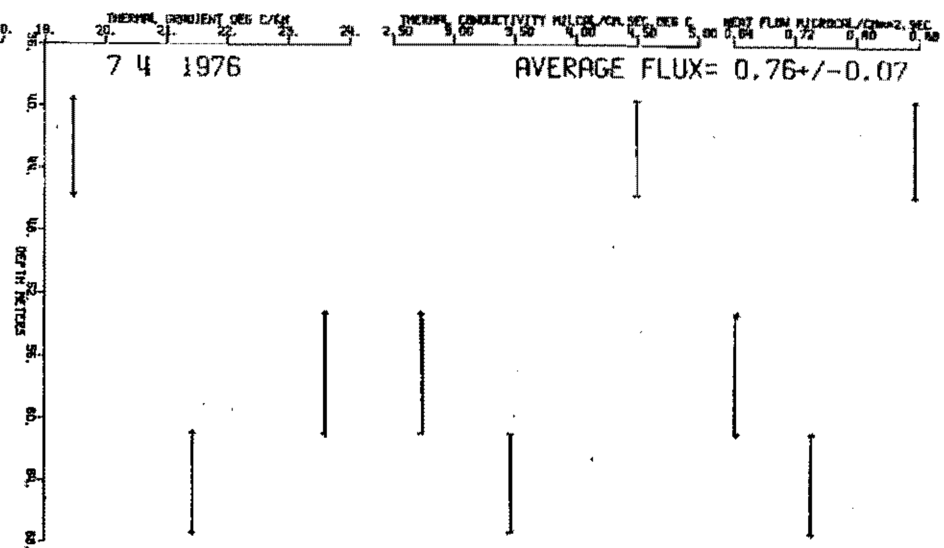
DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
39.62	45.72	4.50	19.46	0.88
53.34	60.96	2.74	23.61	0.65
60.96	67.36	3.48	21.44	0.75

AVERAGE HEAT FLUX= 0.76 +/- 0.07 H.F.U. STD DEV 0.115

METHOD #2 FLUX= 0.74 H.F.U. # OF CONDUCTIVITIES= 3.0
UPPER DEPTH 39.62 LOWER DEPTH 67.36 METERS


TEMPERATURE DEGREES C
NDSWC 2180 7 4 1976
DEPTH METERS


TEMPERATURE DEGREES C
NDSWC 2180
DEPTH METERS


THERMAL GRADIENT DEG C/KM
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
7 4 1976
AVERAGE FLUX= 0.76+/-0.07
DEPTH METERS

NDSWC 4509 USGS OBSERVATION WATER WELL
GRANT COUNTY 135N 90W SECTION 23 BBB1
46 30' 0" NORTH LATITUDE 101 57' 51" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG= 7.15 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
6 19 1976	5 2 1973	5 1 1973	5 2 1973

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 1143
CASING SIZE 5.08CM ELEVATION 313.64 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	10210.00	0.0	24.20	-569.45
50.00	14500.00	15.24	15.52	-174.28
100.00	16200.00	30.48	12.87	-111.14
150.00	17400.00	45.72	11.17	-63.98
200.00	18150.00	60.96	10.20	-44.20
245.00	18638.00	74.68	9.59	-20.91
255.00	18690.00	77.72	9.53	35.92
295.00	18335.00	89.92	9.96	34.84
305.00	18250.00	92.96	10.07	20.73
345.00	18050.00	105.16	10.32	28.40
356.00	17975.00	108.51	10.42	18.16
395.00	17807.00	120.40	10.63	27.15
405.00	17743.00	123.44	10.72	24.75
445.00	17513.00	135.64	11.02	43.33
455.00	17415.00	138.68	11.15	12.15
495.00	17306.00	150.88	11.30	70.09
505.00	17150.00	153.92	11.51	30.78
545.00	16880.00	166.12	11.89	18.50
555.00	16840.00	169.16	11.94	23.81
595.00	16635.00	181.36	12.23	44.69
605.00	16540.00	184.40	12.37	27.17
645.00	16311.00	196.60	12.70	28.91
656.00	16245.00	199.95	12.80	24.36
695.00	16049.00	211.84	13.09	40.61
705.00	15966.00	214.88	13.21	28.48
745.00	15736.00	227.08	13.56	43.09
755.00	15650.00	230.12	13.69	27.25
795.00	15435.00	242.32	14.02	22.51

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
805.00	15391.00	245.36	14.09	
				33.47
846.00	15125.00	257.86	14.51	
				65.12
856.00	15000.00	260.91	14.71	
				39.99
895.00	14705.00	272.80	15.18	
				-50.70
905.00	14800.00	275.84	15.03	
				19.83
946.00	14648.00	288.34	15.28	
				15.06
956.00	14620.00	291.39	15.32	
				25.06
995.00	14440.00	303.28	15.62	
				39.83
1006.00	14360.00	306.63	15.75	
				24.56
1015.00	14320.00	309.37	15.82	
				27.77
1045.00	14170.00	318.52	16.08	
				81.46
1055.00	14025.00	321.56	16.32	

DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
248.40	249.93	7.30	1.00	0.14
268.22	269.74	7.00	1.00	0.14
298.70	300.22	7.40	1.00	0.14
306.32	307.85	6.89	1.00	0.15

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
245.36	257.86	7.30	33.47	2.44
260.91	272.80	7.00	39.99	2.80
291.39	303.28	7.40	25.06	1.85
303.28	306.63	6.89	39.83	2.74

AVERAGE HEAT FLUX= 2.46 +/- 0.22 H.F.U. STD DEV 0.433

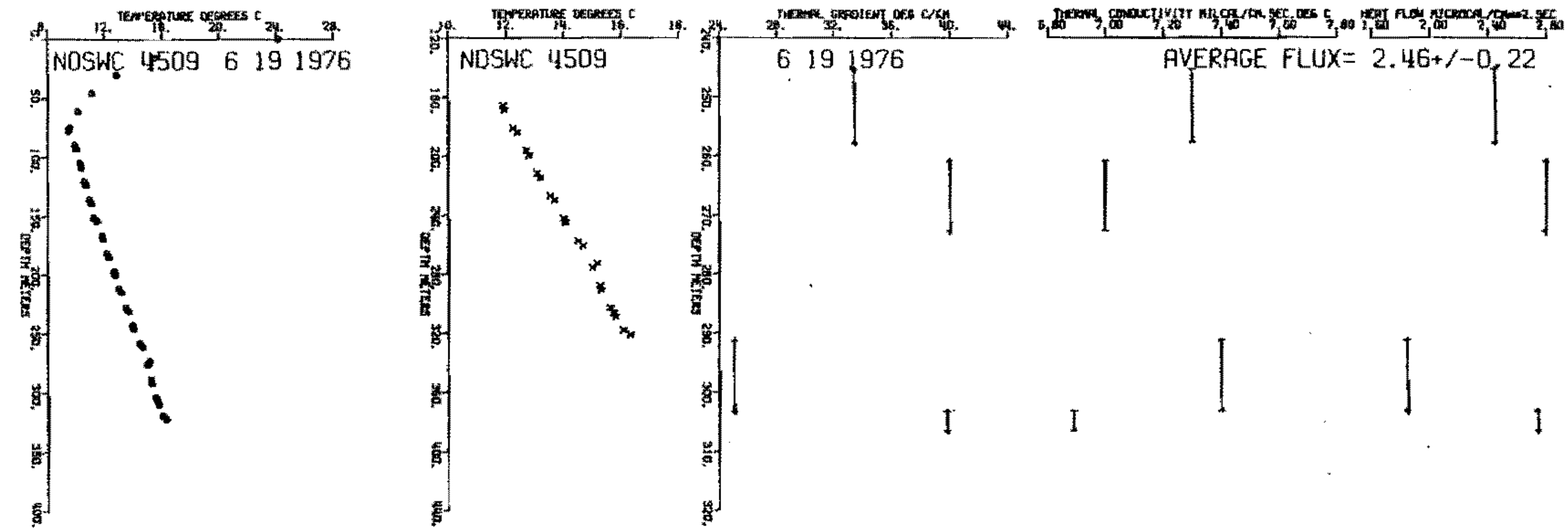
METHOD #2 FLUX= 1.96 H.F.U. # OF CONDUCTIVITIES= 3.0
UPPER DEPTH 153.92 LOWER DEPTH 291.39 METERS

NDSWC 4509 USGS OBSERVATION WATER WELL
GRANT COUNTY 135N 90W SECTION 23 BBBI
46 30' 0"NORTH LATITUDE 101 57' 51" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=15.45 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
3 31 1976	5 2 1973	5 1 1973	5 2 1973

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 1063
CASING SIZE 5.08CM ELEVATION 719.94 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	20850.00	0.0	7.05	
				17.75
50.00	20600.00	15.24	7.33	
				60.01
100.00	19780.00	30.48	8.24	
				16.60
150.00	19560.00	45.72	8.49	
				21.29
204.00	19260.00	62.18	8.84	
				21.79
250.50	19000.00	76.35	9.15	
				32.95
300.00	18590.00	91.44	9.65	
				23.33
350.50	18300.00	106.83	10.01	
				22.14
400.00	18035.00	121.92	10.34	
				29.39
451.00	17680.00	137.46	10.80	
				35.41
500.00	17285.00	152.40	11.33	
				19.85
550.00	17065.00	167.64	11.63	
				33.13
600.00	16705.00	182.88	12.14	
				24.93
650.00	16440.00	198.12	12.52	
				25.87
700.00	16170.00	213.36	12.91	
				29.38
750.00	15870.00	228.60	13.36	
				31.00
800.00	15560.00	243.84	13.83	
				29.68
850.00	15270.00	259.08	14.28	
				32.18
900.00	14960.00	274.32	14.77	
				26.48
950.00	14710.00	289.56	15.18	
				24.83
1000.00	14480.00	304.80	15.55	
				28.08
1050.00	14225.00	320.04	15.98	
				15.81
1073.00	14160.00	327.05	16.09	



NOSWC 4509 6 19 1976
TEMPERATURE DEGREES C
DEPTH METERS
NOSWC 4509
TEMPERATURE DEGREES C
DEPTH METERS
6 19 1976
THERMAL GRADIENT DEG C/KM
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 2.46+/-0.22

NDSWC 4509 USGS OBSERVATION WATER WELL

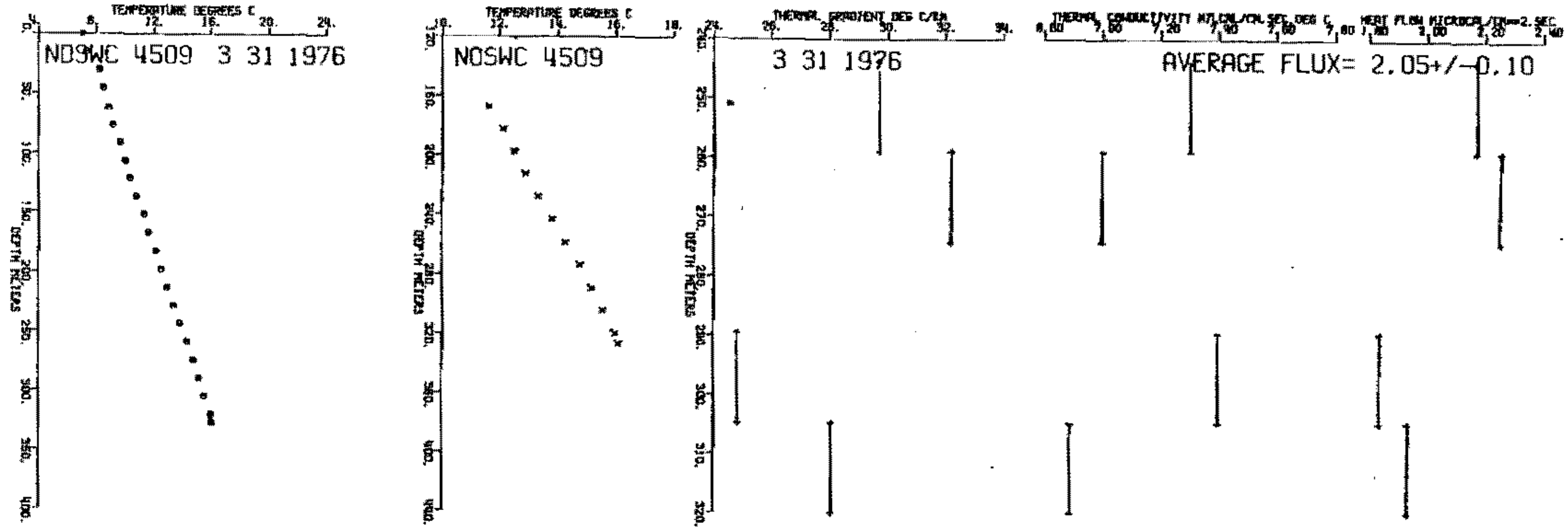
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
248.40	249.93	7.30	1.00	0.14
268.22	269.74	7.00	1.00	0.14
298.70	300.22	7.40	1.00	0.14
306.32	307.85	6.89	1.00	0.15

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
243.84	259.08	7.30	29.68	2.17
259.08	274.32	7.00	32.18	2.25
289.56	304.80	7.40	24.83	1.84
304.80	320.04	6.89	28.08	1.93

AVERAGE HEAT FLUX= 2.05 +/- 0.10 H.F.U. STD DEV 0.194

METHOD #2 FLUX= 1.98 H.F.U. # OF CONDUCTIVITIES= 3.0
UPPER DEPTH 152.40 LOWER DEPTH 289.56 METERS


TEMPERATURE DEGREES C
NOSWC 4509 3 31 1976
DEPTH METERS
TEMPERATURE DEGREES C
NOSWC 4509
DEPTH METERS
THERMAL GRADIENT DEG C/KM
3 31 1976
DEPTH METERS
THERMAL CONDUCTIVITY
HEAT FLOW
AVERAGE FLUX= 2.05+/-0.10

NDSWC 4811 PRIVATE WATER WELL
SLOPE COUNTY 136N 100W SECTION 31 DDD
46 32' 29'' NORTH LATITUDE 103 16' 50'' WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=18.30 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
3 27 1976	7 15 1975	7 1 1975	7 15 1975

DRILLING PERIOD= 14 DAYS DAYS SINCE 1ST PERIOD= 255
CASING SIZE 10.16CM ELEVATION 877.82 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	20300.00	0.0	5.35	
				69.81
50.00	19375.00	15.24	6.41	
				52.66
100.00	18710.00	30.48	7.21	
				21.98
200.00	18175.00	60.96	7.88	
				37.93
260.00	17640.00	79.25	8.58	
				38.29
300.00	17290.00	91.44	9.04	
				79.71
351.00	16400.00	106.98	10.28	
				43.99
400.00	15950.00	121.92	10.94	
				71.83
452.00	15220.00	137.77	12.08	
				43.39
500.00	14830.00	152.40	12.71	
				58.14
550.00	14305.00	167.64	13.60	
				36.12
600.00	13990.00	182.88	14.15	
				45.43
652.00	13590.00	198.73	14.87	
				21.01
700.00	13420.00	213.36	15.18	
				31.37
750.00	13160.00	228.60	15.65	
				29.60
800.00	12920.00	243.84	16.11	
				35.37
850.00	12640.00	259.08	16.64	
				40.24
900.00	12330.00	274.32	17.26	
				40.11
950.00	12030.00	289.56	17.87	
				48.27
1000.00	11680.00	304.80	18.60	
				42.74
1050.00	11380.00	320.04	19.26	
				44.82
1100.00	11075.00	335.28	19.94	
				51.82
1150.00	10730.00	350.52	20.73	
				33.24
1200.00	10515.00	365.76	21.24	
				40.45
1250.00	10260.00	381.00	21.85	
				54.11
1300.00	9930.00	396.24	22.68	
				72.53
1388.00	9200.00	423.06	24.62	

NDSWC 4811 PRIVATE WATER WELL

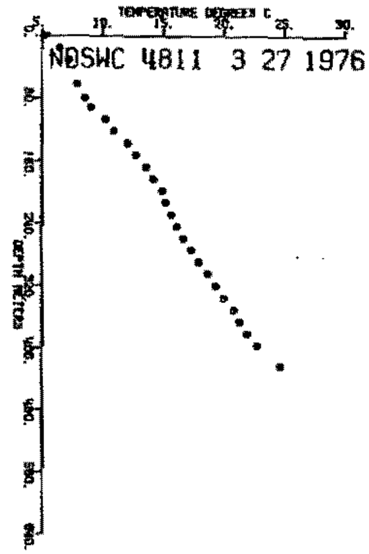
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
86.96	88.39	5.33	1.00	0.19
92.96	94.48	4.32	1.00	0.23
190.50	192.02	4.14	1.00	0.24
217.93	219.45	4.95	1.00	0.20
224.02	225.55	4.47	1.00	0.22
230.12	231.64	3.73	1.00	0.27
236.22	237.74	4.44	1.00	0.23
242.31	243.80	4.77	1.00	0.21
248.41	249.93	3.97	1.00	0.25
254.50	256.03	5.80	1.00	0.17
260.60	262.12	4.52	2.00	0.22
268.22	669.75	3.79	1.00	0.26
275.00	275.84	4.42	2.00	0.23
280.41	281.94	4.56	1.00	0.22
286.51	288.03	4.68	1.00	0.21
304.80	306.32	4.83	1.00	0.21
310.90	312.42	4.10	1.00	0.24
317.00	318.52	4.90	2.00	0.20
335.28	336.80	3.61	1.00	0.28
347.47	349.00	3.83	1.00	0.26
353.57	355.09	4.21	1.00	0.24
373.38	374.90	3.61	1.00	0.28
393.19	394.71	3.82	1.00	0.26

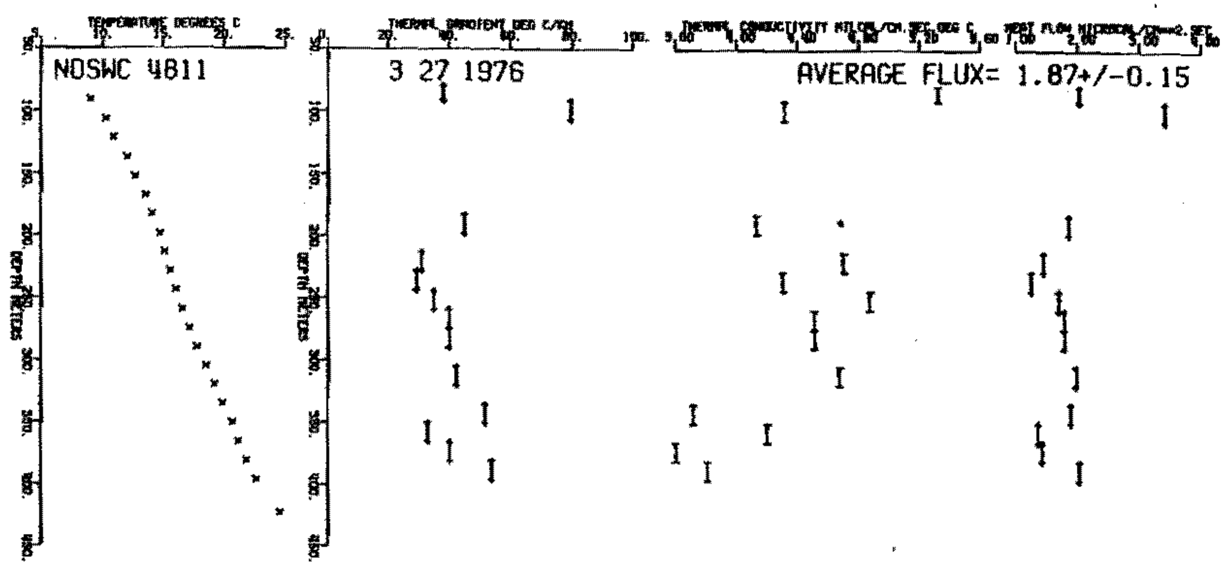
HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
79.25	91.44	5.33	38.29	2.04
91.44	106.98	4.32	79.71	3.44
182.88	198.73	4.14	45.43	1.88
213.36	228.60	4.71	31.37	1.48
228.60	243.84	4.31	29.60	1.28
243.84	259.08	4.88	35.37	1.73
259.08	274.32	4.52	40.24	1.82
274.32	289.56	4.52	40.11	1.81
304.80	320.04	4.68	42.74	2.00
335.28	350.52	3.72	51.82	1.93
350.52	365.76	4.21	33.24	1.40
365.76	381.00	3.61	40.45	1.46
381.00	396.24	3.82	54.11	2.07

AVERAGE HEAT FLUX= 1.87 +/- 0.15 H.F.U. STD DEV 0.539

METHOD #2 FLUX= 1.95 H.F.U. # OF CONDUCTIVITIES=25.0
UPPER DEPTH 79.25 LOWER DEPTH 396.24 METERS


TEMPERATURE DEGREES C
NOSWC 4811 3 27 1976
DEPTH METERS


TEMPERATURE DEGREES C
NOSWC 4811
DEPTH METERS
THERMAL GRADIENT DEG C/KM
3 27 1976
DEPTH METERS
AVERAGE FLUX= 1.87+/-0.15

NDSWC 4811 PRIVATE WATER WELL
SLOPE COUNTY 136N 100W SECTION 31 DDD
46 32' 29'' NORTH LATITUDE 103 16' 50'' WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=21.50 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
10 6 1976	7 15 1975	7 1 1975	7 15 1975

DRILLING PERIOD= 14 DAYS DAYS SINCE 1ST PERIOD= 448
CASING SIZE 10.16CM ELEVATION 877.82 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	18545.00	0.0	9.70	
				2.03
50.00	18520.00	15.24	9.74	
				9.74
100.00	18400.00	30.48	9.88	
				-12.16
150.00	18550.00	45.72	9.70	
				41.03
200.00	18050.00	60.96	10.32	
				29.75
250.00	17697.00	76.20	10.78	
				11.76
300.00	17560.00	91.44	10.96	
				99.92
350.00	16465.00	106.68	12.48	
				83.59
400.00	15610.00	121.92	13.75	
				92.34
450.00	14720.00	137.16	15.16	
				19.37
500.00	14540.00	152.40	15.46	
				54.23
550.00	14050.00	167.64	16.28	
				27.36
600.00	13810.00	182.88	16.70	
				33.21
650.00	13525.00	198.12	17.20	
				87.10
700.00	12810.00	213.36	18.53	
				51.51
751.00	12400.00	228.90	19.33	
				12.13
805.00	12300.00	245.36	19.53	
				20.67
850.00	12160.00	259.08	19.82	
				14.77
900.00	12050.00	274.32	20.04	
				42.44
950.00	11740.00	289.56	20.69	
				39.46
1000.00	11460.00	304.80	21.29	
				11.96
1060.00	11360.00	323.09	21.51	
				133.04
1100.00	10650.00	335.28	23.13	
				28.31
1150.00	10470.00	350.52	23.56	
				17.57
1200.00	10360.00	365.76	23.83	
				11.29
1250.00	10290.00	381.00	24.00	
				85.18
1300.00	9780.00	396.24	25.30	
				35.63
1350.00	9575.00	411.48	25.84	
				29.56

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
1400.00	9407.00	426.72	26.29	
				17.37
1450.00	9310.00	441.96	26.56	
				2.24
1490.00	9300.00	454.15	26.58	

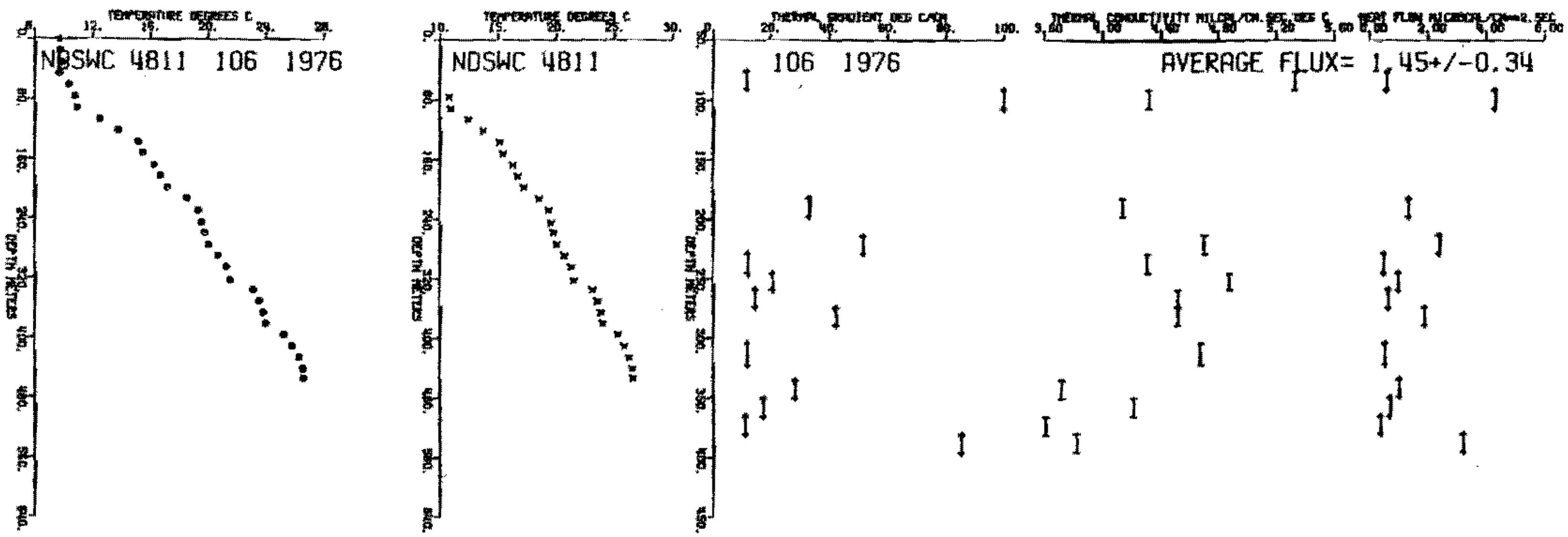
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
86.96	88.39	5.33	1.00	0.19
92.96	94.48	4.32	1.00	0.23
190.50	192.02	4.14	1.00	0.24
217.93	219.45	4.95	1.00	0.20
224.02	225.55	4.47	1.00	0.22
230.12	231.64	3.73	1.00	0.27
236.22	237.74	4.44	1.00	0.23
242.31	243.80	4.77	1.00	0.21
248.41	249.93	3.97	1.00	0.25
254.50	256.03	5.80	1.00	0.17
260.60	262.12	4.52	2.00	0.22
268.22	669.75	3.79	1.00	0.26
275.00	275.84	4.42	2.00	0.23
280.41	281.94	4.56	1.00	0.22
286.51	288.03	4.68	1.00	0.21
304.80	306.32	4.83	1.00	0.21
310.90	312.42	4.10	1.00	0.24
317.00	318.52	4.90	2.00	0.20
335.28	336.80	3.61	1.00	0.28
347.47	349.00	3.83	1.00	0.26
353.57	355.09	4.21	1.00	0.24
373.38	374.90	3.61	1.00	0.28
393.19	394.71	3.82	1.00	0.26

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
76.20	91.44	5.33	11.76	0.63
91.44	106.68	4.32	99.92	4.32
182.88	198.12	4.14	33.21	1.37
213.36	228.90	4.71	51.51	2.43
228.90	245.36	4.31	12.13	0.52
245.36	259.08	4.88	20.67	1.01
259.08	274.32	4.52	14.77	0.67
274.32	289.56	4.52	42.44	1.92
304.80	323.09	4.68	11.96	0.56
335.28	350.52	3.72	28.31	1.05
350.52	365.76	4.21	17.57	0.74
365.76	381.00	3.61	11.29	0.41
381.00	396.24	3.82	85.18	3.25

AVERAGE HEAT FLUX= 1.45 +/- 0.34 H.F.U. STD DEV 1.209

METHOD #2 FLUX= 1.95 H.F.U. # OF CONDUCTIVITIES=25.0
UPPER DEPTH 60.96 LOWER DEPTH 396.24 METERS


NDSWC 4811 106 1976
TEMPERATURE DEGREES C
DEPTH METERS
NDSWC 4811
TEMPERATURE DEGREES C
DEPTH METERS
106 1976
THERMAL GRADIENT DEG C/KM
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.45+/-0.34
DEPTH METERS

NDSWC 4485 USGS OBSERVATION WATER WELL
GRANT COUNTY 137N 88W SECTION 21 DDC
46 39' 38" NORTH LATITUDE 101 47' 6" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=19.00 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
3 31 1976	10 5 1972	10 4 1972	10 5 1972

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 1272
CASING SIZE 5.08CM ELEVATION 643.13 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	14680.00	0.0	15.23	
				-248.10
50.00	17200.00	15.24	11.44	
				-153.21
101.00	19075.00	30.78	9.06	
				-15.62
151.00	19276.00	46.02	8.82	
				15.94
200.00	19075.00	60.96	9.06	
				23.26
250.00	18780.00	76.20	9.42	
				24.51
300.00	18475.00	91.44	9.79	
				25.62
352.00	18150.00	107.29	10.20	
				21.74
400.00	17900.00	121.92	10.51	
				28.96
450.00	17560.00	137.16	10.96	
				26.64
500.00	17260.00	152.40	11.36	
				30.85
550.00	16920.00	167.64	11.83	
				25.97
600.00	16640.00	182.88	12.23	
				27.41
650.00	16350.00	198.12	12.65	
				26.93
702.00	16060.00	213.97	13.07	
				21.49
750.00	15850.00	228.60	13.39	
				29.04
800.00	15560.00	243.84	13.83	
				23.49
850.00	15330.00	259.08	14.19	
				23.76
900.00	15100.00	274.32	14.55	
				7.14
922.00	15070.00	281.03	14.60	

NOSWC 4485 USGS OBSERVATION WATER WELL

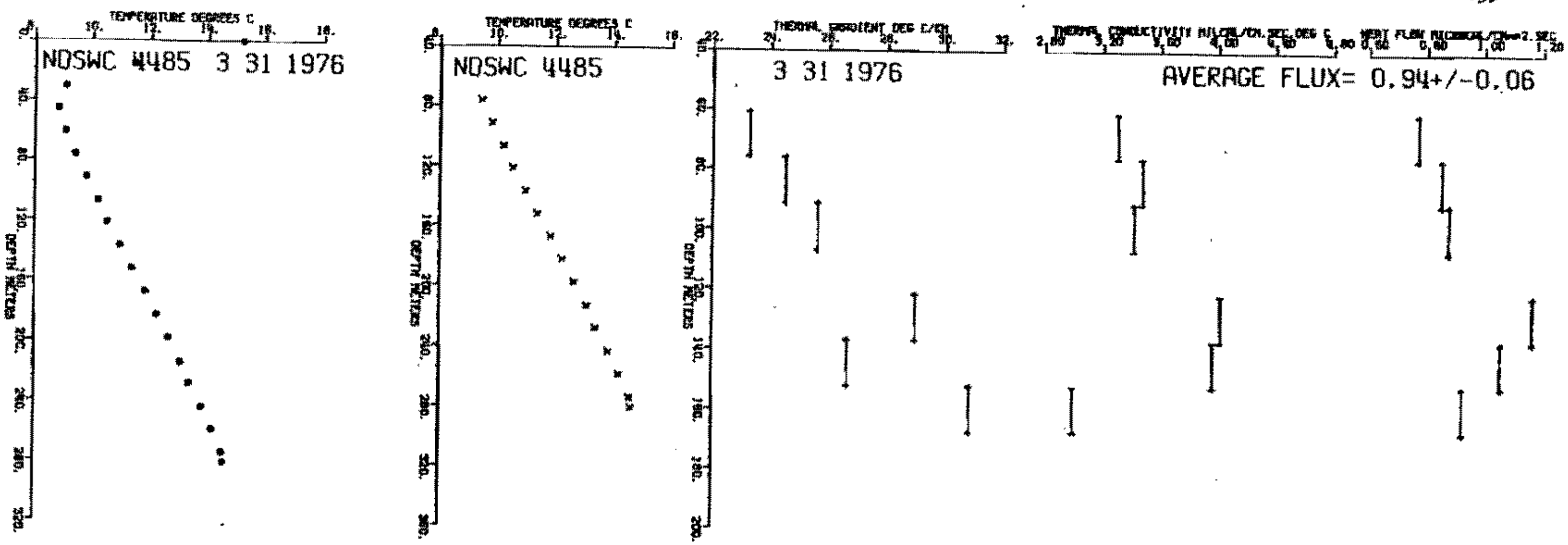
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
73.15	74.68	3.30	1.00	0.30
86.87	88.39	3.47	1.00	0.29
99.60	100.58	3.42	1.00	0.29
134.11	135.64	4.02	1.00	0.25
150.57	152.10	3.97	1.00	0.25
150.88	152.40	3.60	1.00	0.28
160.00	161.54	3.00	1.00	0.33

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
60.96	76.20	3.30	23.26	0.77
76.20	91.44	3.47	24.51	0.85
91.44	107.29	3.42	25.62	0.88
121.92	137.16	4.02	28.96	1.16
137.16	152.40	3.97	26.64	1.06
152.40	167.64	3.00	30.85	0.93

AVERAGE HEAT FLUX= 0.94 +/- 0.06 H.F.U. STD DEV 0.146

METHOD #2 FLUX= 0.91 H.F.U. # OF CONDUCTIVITIES= 7.0
UPPER DEPTH 60.96 LOWER DEPTH 167.64 METERS


NDSWC 4485 3 31 1976
TEMPERATURE DEGREES C
DEPTH METERS
NDSWC 4485
TEMPERATURE DEGREES C
DEPTH METERS
3 31 1976
THERMAL GRADIENT DEG C/KM
DEPTH METERS
AVERAGE FLUX= 0.94+/-0.06

NDSWC 4485 USGS OBSERVATION WATER WELL
GRANT COUNTY 137N 88W SECTION 21 DDC
46 39' 38" NORTH LATITUDE 101 47' 6" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=20.30 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
10 5 1976	10 5 1972	10 4 1972	10 5 1972

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 1460
CASING SIZE 5.08CM ELEVATION 643.13 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	19900.00	0.0	8.10	
				-160.57
50.00	22200.00	15.24	5.66	
				-80.82
101.00	23500.00	30.78	4.40	
				22.10
150.00	23150.00	45.72	4.73	
				31.62
200.00	22650.00	60.96	5.21	
				44.98
250.00	21960.00	76.20	5.90	
				58.44
300.00	21100.00	91.44	6.79	
				50.35
350.00	20390.00	106.68	7.56	
				24.85
400.00	20050.00	121.92	7.93	
				56.55
450.00	19300.00	137.16	8.80	
				87.76
500.00	18200.00	152.40	10.13	
				44.09
550.00	17675.00	167.64	10.81	
				80.76
600.00	16775.00	182.88	12.04	
				82.06
651.00	15900.00	198.42	13.31	
				40.90
700.00	15500.00	213.36	13.92	
				60.53
760.00	14800.00	231.65	15.03	
				58.85
825.00	14100.00	251.46	16.20	
				-55.08
875.00	14600.00	266.70	15.36	
				27.14
900.00	14475.00	274.32	15.56	
				178.74
940.00	13230.00	286.51	17.74	

NDSWC 4485 USGS OBSERVATION WATER WELL

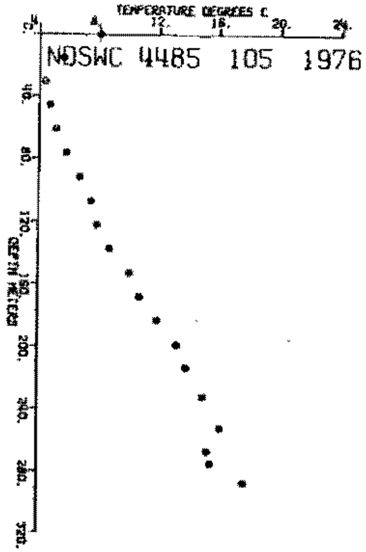
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
73.15	74.68	3.30	1.00	0.30
86.87	88.39	3.47	1.00	0.29
99.60	100.58	3.42	1.00	0.29
134.11	135.64	4.02	1.00	0.25
150.57	152.10	3.97	1.00	0.25
150.88	152.40	3.60	1.00	0.28
160.00	161.54	3.00	1.00	0.33

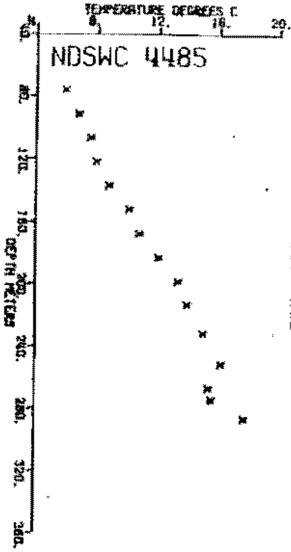
HEAT FLUX CALCULATION INTERVAL METHOD

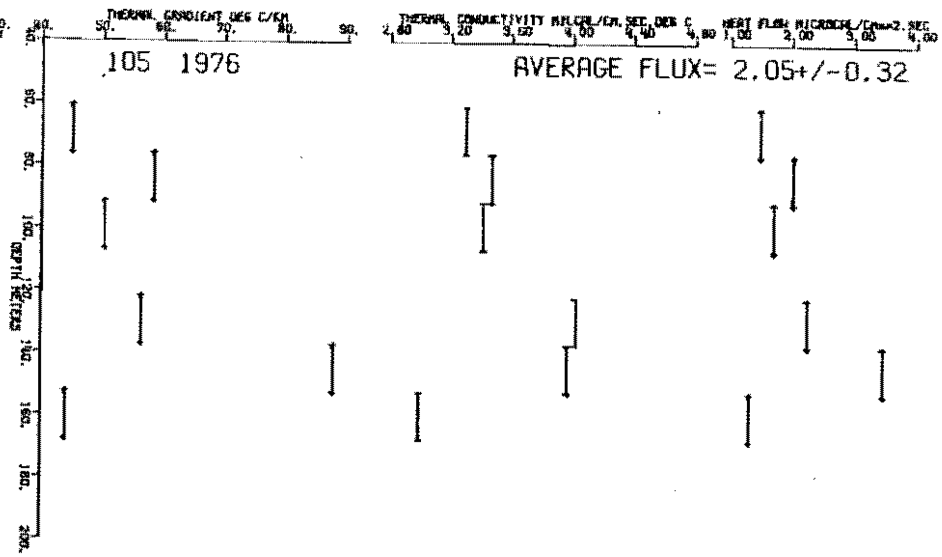
DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
60.96	76.20	3.30	44.98	1.48
76.20	91.44	3.47	58.44	2.03
91.44	106.68	3.42	50.35	1.72
121.92	137.16	4.02	56.55	2.27
137.16	152.40	3.97	87.76	3.48
152.40	167.64	3.00	44.09	1.32

AVERAGE HEAT FLUX= 2.05 +/- 0.32 H.F.U. STD DEV 0.783

METHOD #2 FLUX= 1.84 H.F.U. # OF CONDUCTIVITIES= 7.0
UPPER DEPTH 60.96 LOWER DEPTH 167.64 METERS


TEMPERATURE DEGREES C
NDSWC 4485 105 1976
DEPTH METERS


TEMPERATURE DEGREES C
NDSWC 4485
DEPTH METERS


THERMAL GRADIENT DEG C/KM
105 1976
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 2.05+/-0.32

NDSWC 4511 USGS OBSERVATION WATER WELL
GRANT COUNTY 137N 89W SECTION 9 ABA1
46 42' 08" NORTH LATITUDE 101 54' 48" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=16.24 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
10 7 1976	5 8 1973	5 7 1973	5 8 1973

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 1247
CASING SIZE 5.08CM ELEVATION 702.56 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	21480.00	0.0	6.39	
				101.36
50.00	20050.00	15.24	7.93	
				16.69
100.00	19825.00	30.48	8.19	
				16.93
150.00	19600.00	45.72	8.45	
				34.55
200.00	19150.00	60.96	8.97	
				26.98
251.00	18800.00	76.50	9.39	
				54.00
301.00	18135.00	91.74	10.22	
				39.48
350.00	17675.00	106.68	10.81	
				24.03
400.00	17400.00	121.92	11.17	
				14.99
450.00	17232.00	137.16	11.40	
				39.87
500.00	16795.00	152.40	12.01	
				28.55
550.00	16490.00	167.64	12.44	
				14.27
600.00	16340.00	182.88	12.66	
				33.39
650.00	15995.00	198.12	13.17	
				31.38
711.00	15610.00	216.71	13.75	
				23.41
750.00	15430.00	228.60	14.03	
				34.25
800.00	15098.00	243.84	14.55	
				28.11
850.00	14830.00	259.08	14.98	
				31.08
900.00	14540.00	274.32	15.46	
				16.07
951.00	14390.00	289.86	15.70	
				10.10
1000.00	14300.00	304.80	15.86	
				67.24
1036.00	13870.00	315.77	16.59	

NDSWC 4511 USGS OBSERVATION WATER WELL

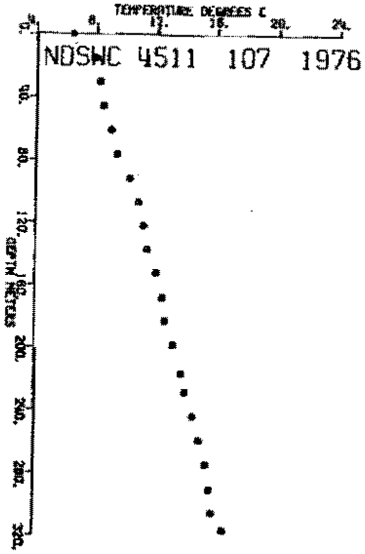
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
54.86	56.39	3.42	1.00	0.29
65.53	67.06	3.97	1.00	0.25
89.92	91.44	3.00	1.00	0.33
106.68	108.20	3.92	1.00	0.26
115.83	117.35	4.08	1.00	0.25

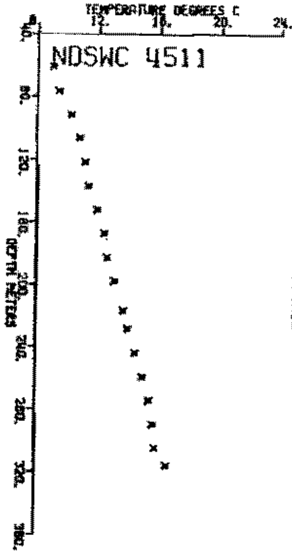
HEAT FLUX CALCULATION INTERVAL METHOD

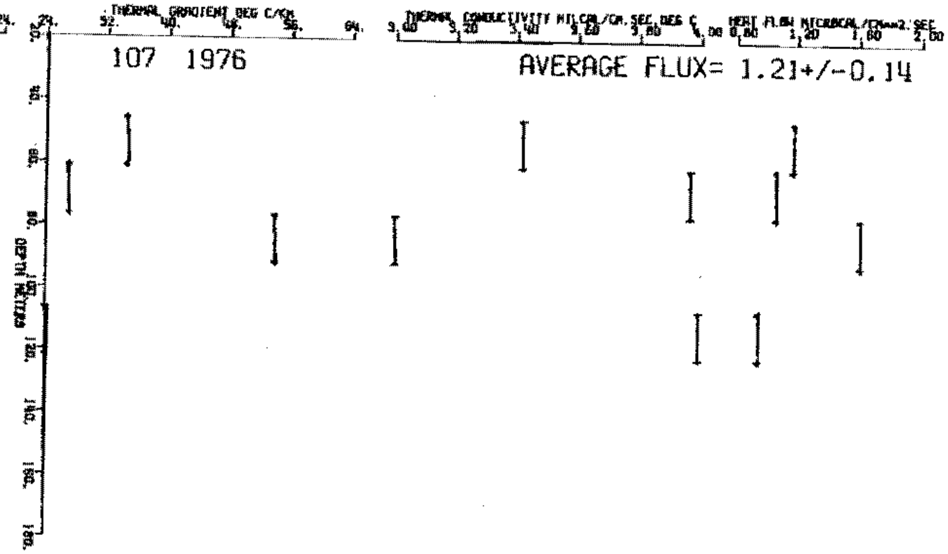
DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
45.72	60.96	3.42	34.55	1.18
60.96	76.50	3.97	26.98	1.07
76.50	91.74	3.00	54.00	1.62
106.68	121.92	4.00	24.03	0.96

AVERAGE HEAT FLUX= 1.21 +/- 0.14 H.F.U. STD DEV 0.289

METHOD #2 FLUX= 1.30 H.F.U. # OF CONDUCTIVITIES= 5.0
UPPER DEPTH 45.72 LOWER DEPTH 121.92 METERS


TEMPERATURE DEGREES C
NDSWC 4511 107 1976
DEPTH METERS


TEMPERATURE DEGREES C
NDSWC 4511
DEPTH METERS


THERMAL GRADIENT DEG C/KM
107 1976
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.21+/-0.14

NDSWC 4511 USGS OBSERVATION WATER WELL
GRANT COUNTY 137N 89W SECTION 09 ABA1
46 42' 08" NORTH LATITUDE 101 54' 48" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG= 9.20 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
3 31 1976	5 8 1973	5 7 1973	5 8 1973

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 1057
CASING SIZE 5.08CM ELEVATION 702.56 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	14000.00	0.0	16.37	
				-339.15
50.00	17380.00	15.24	11.20	
				-62.43
100.00	18110.00	30.48	10.25	
				-21.82
150.00	18375.00	45.72	9.91	
				-16.63
200.00	18580.00	60.96	9.66	
				0.0
250.00	18580.00	76.20	9.66	
				30.98
300.00	18200.00	91.44	10.13	
				19.98
350.00	17960.00	106.68	10.44	
				24.11
400.00	17675.00	121.92	10.81	
				23.13
450.00	17410.00	137.16	11.16	
				20.60
500.00	17180.00	152.40	11.47	
				33.77
550.00	16810.00	167.64	11.99	
				29.94
600.00	16490.00	182.88	12.44	
				28.68
650.00	16190.00	198.12	12.88	
				27.36
700.00	15910.00	213.36	13.30	
				26.35
751.00	15640.00	228.90	13.71	
				24.88
800.00	15400.00	243.84	14.08	
				22.67
850.00	15180.00	259.08	14.42	
				37.14
905.00	14790.00	275.84	15.05	
				34.66
950.00	14500.00	289.56	15.52	
				23.05
1000.00	14290.00	304.80	15.87	
				18.51
1036.00	14170.00	315.77	16.08	

NDSWC 4511 USGS OBSERVATION WATER WELL

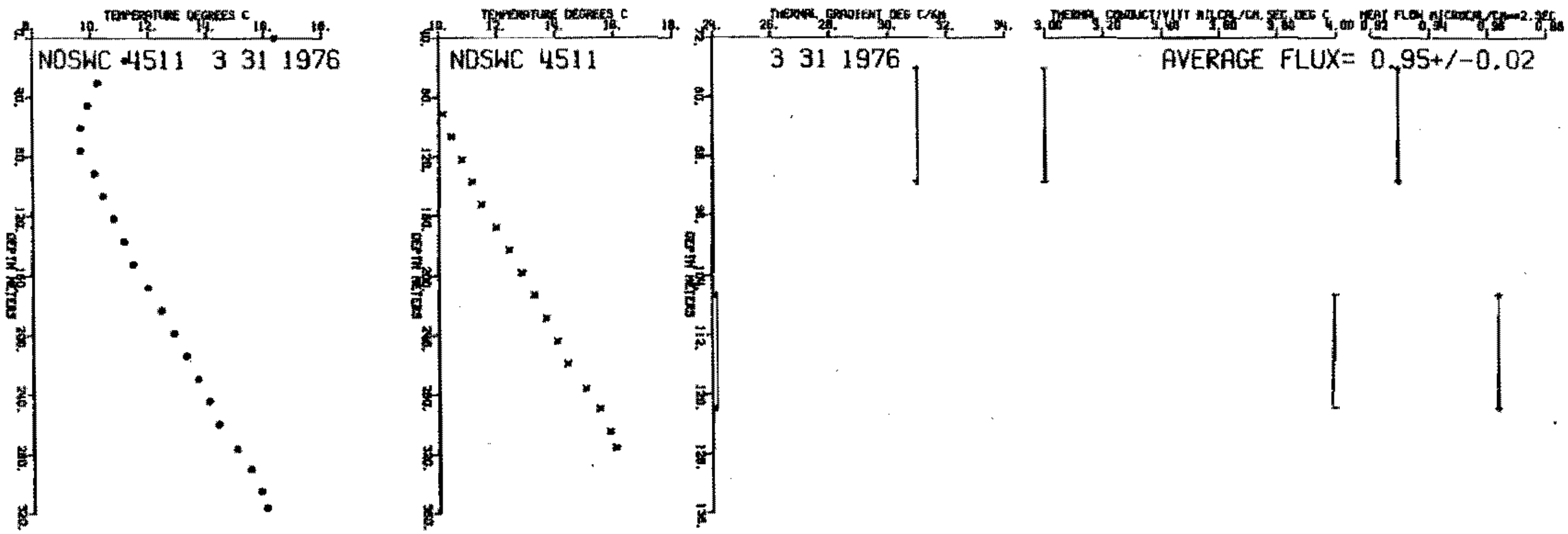
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
89.92	91.44	3.00	1.00	0.33
106.68	108.20	3.92	1.00	0.26
115.83	117.35	4.08	1.00	0.25

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
76.20	91.44	3.00	30.98	0.93
106.68	121.92	4.00	24.11	0.96

AVERAGE HEAT FLUX= 0.95 +/- 0.02 H.F.U. STD DEV 0.025

METHOD #2 FLUX= 0.90 H.F.U. # OF CONDUCTIVITIES= 3.0
UPPER DEPTH 76.20 LOWER DEPTH 121.92 METERS


TEMPERATURE DEGREES C
NOSWC 4511 3 31 1976
DEPTH METERS
TEMPERATURE DEGREES C
NOSWC 4511
DEPTH METERS
THERMAL GRADIENT DEG C/KM
3 31 1976
DEPTH METERS
THERMAL CONDUCTIVITY
HEAT FLOW
AVERAGE FLUX= 0.95+/-0.02

NDSWC 3690 USGS OBSERVATION WATER WELL
STARK COUNTY 138N 99W SECTION 24 CCC
46 44' 48" NORTH LATITUDE 103 07' 29" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=22.45 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
7 26 1975	12 2 1968	12 1 1968	12 2 1968

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 2426
CASING SIZE 5.08CM ELEVATION 798.58 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	6870.00	0.0	34.53	
				-398.31
202.00	18300.00	61.57	10.01	
				14.35
250.00	18133.00	76.20	10.22	
				42.37
300.00	17630.00	91.44	10.86	
				52.56
350.00	17040.00	106.68	11.67	
				52.46
400.00	16475.00	121.92	12.46	
				28.62
451.00	16170.00	137.46	12.91	
				50.59
500.00	15667.00	152.40	13.67	
				49.77
550.00	15180.00	167.64	14.42	
				20.79
600.00	14980.00	182.88	14.74	
				59.77
652.00	14400.00	198.73	15.69	
				6.89
700.00	14340.00	213.36	15.79	
				45.37
750.00	13935.00	228.60	16.48	
				-63.09
763.00	14080.00	232.56	16.23	

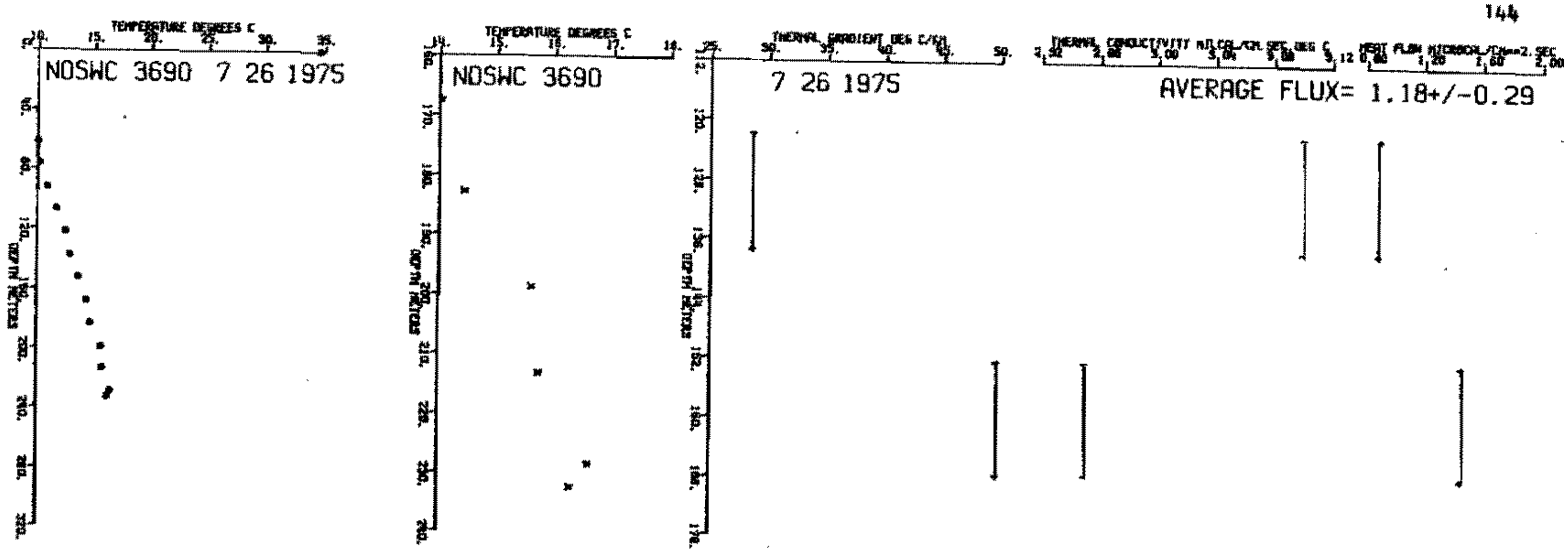
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
137.46	152.00	3.10	1.00	0.32
153.00	167.30	2.95	1.00	0.34

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
121.92	137.46	3.10	28.62	0.89
152.40	167.64	2.95	49.77	1.47

AVERAGE HEAT FLUX= 1.18 +/- 0.29 H.F.U. STD DEV 0.411

METHOD #2 FLUX= 1.09 H.F.U. # OF CONDUCTIVITIES= 1.0
UPPER DEPTH 152.40 LOWER DEPTH 228.60 METERS


TEMPERATURE DEGREES C
NOSWC 3690 7 26 1975
DEPTH METERS
TEMPERATURE DEGREES C
NOSWC 3690
DEPTH METERS
THERMAL GRADIENT DEG C/KM
7 26 1975
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.18+/-0.29

NDSWC 3433 USGS OBSERVATION WATER WELL
MERCER COUNTY 141N 90W SECTION 19 CCD
47 0' 41" NORTH LATITUDE 102 8' 26" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=14.10 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
7 25 1975	6 18 1967	6 14 1967	6 15 1967

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 2960
CASING SIZE 10.16CM ELEVATION 633.98 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	8140.00	0.0	30.03	
				-1409.85
50.00	19520.00	15.24	8.54	
				20.10
100.00	19258.00	30.48	8.85	
				22.48
150.00	18970.00	45.72	9.19	
				21.34
200.00	18701.00	60.96	9.51	
				19.42
250.00	18460.00	76.20	9.81	
				23.69
300.00	18171.00	91.44	10.17	
				32.66
350.00	17781.00	106.68	10.67	
				25.13
400.00	17489.00	121.92	11.05	
				41.56
450.00	17026.00	137.16	11.68	
				33.30
500.00	16665.00	152.40	12.19	
				27.86
550.00	16370.00	167.64	12.62	
				27.86
600.00	16081.00	182.88	13.04	
				7.91
650.00	16000.00	198.12	13.16	
				34.73
700.00	15650.00	213.36	13.69	
				25.39
750.00	15400.00	228.60	14.08	
				24.94
800.00	15158.00	243.84	14.46	
				24.19
850.00	14926.00	259.08	14.83	
				29.12
900.00	14652.00	274.32	15.27	
				23.87
950.00	14432.00	289.56	15.63	
				24.51
1000.00	14210.00	304.80	16.01	
				26.66
1050.00	13973.00	320.04	16.41	
				34.17
1100.00	13676.00	335.28	16.94	
				551.62
1151.00	9700.00	350.82	25.51	
				-530.57
1200.00	13315.00	365.76	17.59	
				12.01
1220.00	13275.00	371.86	17.66	

NOSWC 3433

USGS OBSERVATION WATER WELL

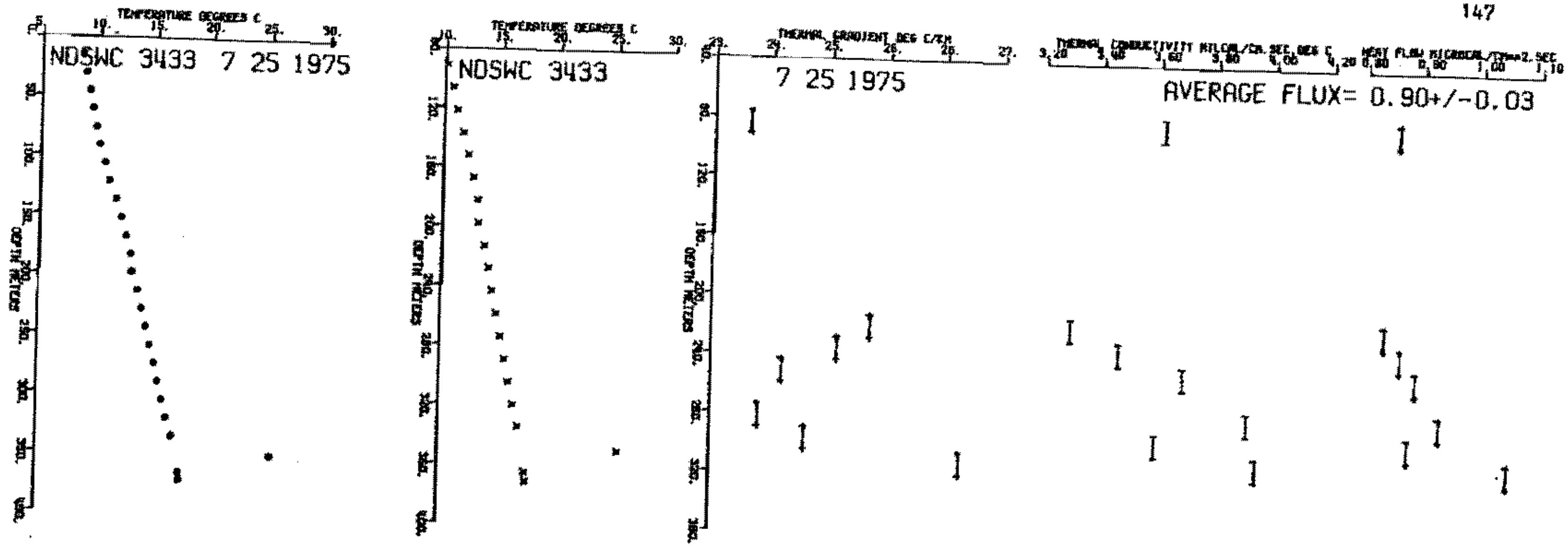
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
79.25	80.77	3.30	1.00	0.30
88.39	89.91	3.93	1.00	0.25
218.54	220.06	3.30	1.00	0.30
232.26	233.78	3.47	1.00	0.29
245.36	246.89	3.42	1.00	0.29
256.03	257.56	3.97	1.00	0.25
280.42	281.94	3.92	1.00	0.26
297.18	298.70	3.60	1.00	0.28
306.32	307.85	3.95	1.00	0.25

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
76.20	91.44	3.61	23.69	0.86
213.36	228.60	3.30	25.39	0.84
228.60	243.84	3.47	24.94	0.87
243.84	259.08	3.69	24.19	0.89
274.32	289.56	3.92	23.87	0.94
289.56	304.80	3.60	24.51	0.88
304.80	320.04	3.95	26.66	1.05

AVERAGE HEAT FLUX= 0.90 +/- 0.03 H.F.U. STD DEV 0.073

METHOD #2 FLUX= 0.98 H.F.U. # OF CONDUCTIVITIES= 9.0
UPPER DEPTH 76.20 LOWER DEPTH 320.04 METERS


TEMPERATURE DEGREES C
NDSWC 3433 7 25 1975
DEPTH METERS
TEMPERATURE DEGREES C
NDSWC 3433
DEPTH METERS
THERMAL GRADIENT DEG C/KM
7 25 1975
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 0.90+/-0.03

NDSWC 3433 USGS OBSERVATION WATER WELL
MERCER COUNTY 141N 90W SECTION 19 CCD
47 0' 41" NORTH LATITUDE 102 8' 26" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=20.10 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
3 30 1976	6 18 1967	6 14 1967	6 15 1967

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 3208
CASING SIZE 10.16CM ELEVATION 633.98 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	15900.00	0.0	13.31	
				-296.30
50.00	19300.00	15.24	8.80	
				14.75
100.00	19110.00	30.48	9.02	
				15.68
150.00	18910.00	45.72	9.26	
				28.60
200.00	18552.00	60.96	9.70	
				16.40
250.00	18350.00	76.20	9.95	
				19.78
300.00	18110.00	91.44	10.25	
				37.90
350.00	17660.00	106.68	10.82	
				28.08
400.00	17340.00	121.92	11.25	
				41.23
450.00	16885.00	137.16	11.88	
				28.55
500.50	16575.00	152.55	12.32	
				23.95
550.00	16325.00	167.64	12.68	
				39.83
600.00	15915.00	182.88	13.29	
				16.37
650.00	15750.00	198.12	13.54	
				3.00
700.00	15720.00	213.36	13.58	
				42.69
750.00	15300.00	228.60	14.23	
				25.87
800.00	15050.00	243.84	14.63	
				20.99
850.00	14850.00	259.08	14.95	
				28.32
900.00	14585.00	274.32	15.38	
				31.17
950.00	14300.00	289.56	15.86	
				24.56
1000.00	14080.00	304.80	16.23	
				36.52
1050.00	13760.00	320.04	16.79	
				23.31
1100.00	13560.00	335.28	17.14	
				21.51
1200.00	13200.00	365.76	17.80	
				9.17
1220.00	13170.00	371.86	17.85	

NDSWC 3433 USGS OBSERVATION WATER WELL

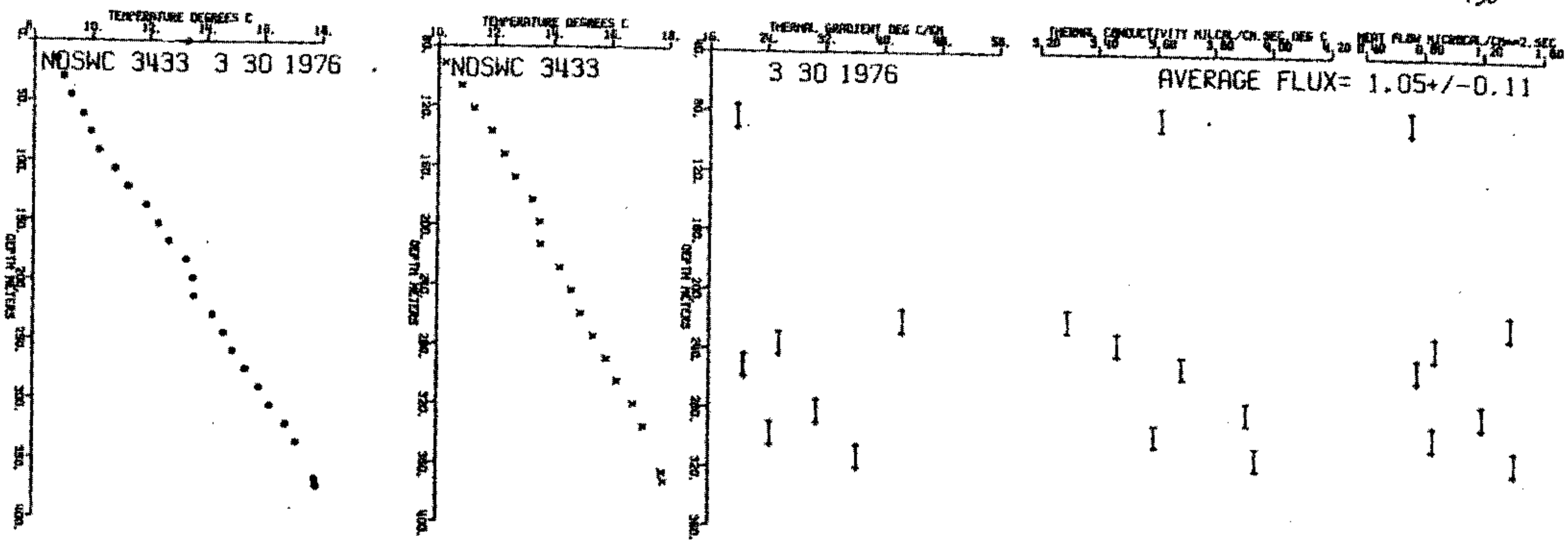
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
79.25	80.77	3.30	1.00	0.30
88.39	89.91	3.93	1.00	0.25
218.54	220.06	3.30	1.00	0.30
232.26	233.78	3.47	1.00	0.29
245.36	246.89	3.42	1.00	0.29
256.03	257.56	3.97	1.00	0.25
280.42	281.94	3.92	1.00	0.26
297.18	298.70	3.60	1.00	0.28
306.32	307.85	3.95	1.00	0.25

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
76.20	91.44	3.61	19.78	0.72
213.36	228.60	3.30	42.69	1.41
228.60	243.84	3.47	25.87	0.90
243.84	259.08	3.69	20.99	0.78
274.32	289.56	3.92	31.17	1.22
289.56	304.80	3.60	24.56	0.88
304.80	320.04	3.95	36.52	1.44

AVERAGE HEAT FLUX= 1.05 +/- 0.11 H.F.U. STD DEV 0.303

METHOD #2 FLUX= 1.02 H.F.U. # OF CONDUCTIVITIES= 9.0
UPPER DEPTH 76.20 LOWER DEPTH 320.04 METERS



TEMPERATURE DEGREES C
NOSWC 3433 3 30 1976
DEPTH METERS
TEMPERATURE DEGREES C
NOSWC 3433
DEPTH METERS
THERMAL GRADIENT DEG C/KM
3 30 1976
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.05+/-0.11

NDSWC 4662 USGS OBSERVATION WATER WELL
DUNN COUNTY 141N 93W SECTION 16 AAA
47 2' 18" NORTH LATITUDE 102 27' 44" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=11.57 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
8 14 1975	6 18 1974	6 17 1974	6 18 1974

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 422
CASING SIZE 5.08CM ELEVATION 657.76 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	13040.00	0.0	18.10	
				-663.09
50.00	20000.00	15.24	7.99	
				29.94
100.00	19600.00	30.48	8.45	
				36.88
150.00	19120.00	45.72	9.01	
				38.38
200.00	18635.00	60.96	9.59	
				20.75
250.00	18379.00	76.20	9.91	
				26.42
301.00	18052.00	91.74	10.32	
				25.50
350.00	17755.00	106.68	10.70	
				30.85
400.00	17400.00	121.92	11.17	
				25.07
451.00	17115.00	137.46	11.56	
				36.06
500.00	16730.00	152.40	12.10	
				28.39
550.00	16428.00	167.64	12.53	
				46.39
600.00	15948.00	182.88	13.24	
				34.59
650.00	15601.00	198.12	13.77	
				44.55
700.00	15166.00	213.36	14.45	
				30.39
750.00	14875.00	228.60	14.91	
				16.86
790.00	14748.00	240.79	15.11	

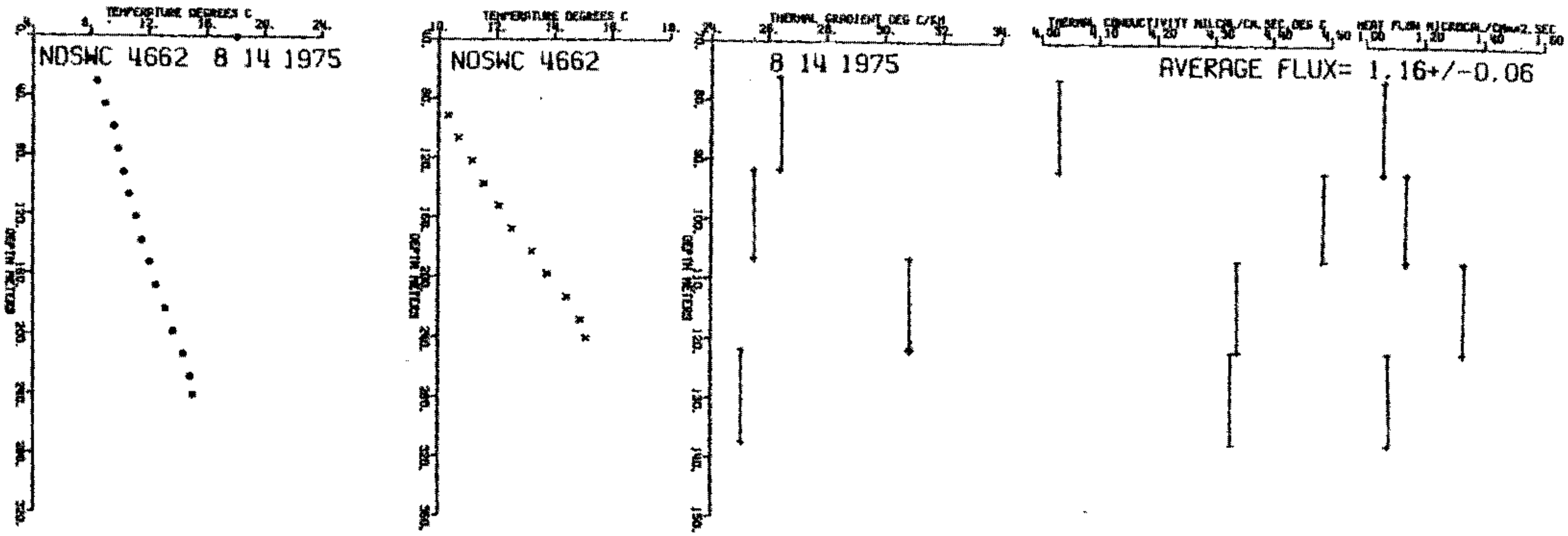
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
82.30	83.82	4.56	1.00	0.22
88.39	89.92	3.50	1.00	0.29
94.49	96.01	4.49	1.00	0.22
106.68	108.20	4.99	1.00	0.20
112.78	114.30	3.69	1.00	0.27
124.97	126.49	4.33	1.00	0.23

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
76.20	91.74	4.03	26.42	1.06
91.74	106.68	4.49	25.50	1.14
106.68	121.92	4.34	30.85	1.34
121.92	137.46	4.33	25.07	1.09

AVERAGE HEAT FLUX= 1.16 +/- 0.06 H.F.U. STD DEV 0.125

METHOD #2 FLUX= 1.13 H.F.U. # OF CONDUCTIVITIES= 6.0
UPPER DEPTH 76.20 LOWER DEPTH 137.46 METERS


NOSWC 4662 8 14 1975
TEMPERATURE DEGREES C
DEPTH METERS
NOSWC 4662
TEMPERATURE DEGREES C
DEPTH METERS
8 14 1975
THERMAL GRADIENT DEG C/KM
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.16+/-0.06

NDSWC 3558 USGS OBSERVATION WATER WELL
OLIVER COUNTY 142N 84W SECTION 24 88A
47 06' 42" NORTH LATITUDE 101 16' 27" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=17.43 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
5 14 1975	12 2 1967	12 1 1967	12 2 1967

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 2718
CASING SIZE 10.16CM ELEVATION 611.43 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	14800.00	0.0	15.03	
				-724.92
30.00	19640.00	9.14	8.40	
				-29.16
60.00	19873.00	18.29	8.13	
				4.00
90.00	19841.00	27.43	8.17	
				10.84
120.00	19754.00	36.58	8.27	
				13.67
150.00	19645.00	45.72	8.40	
				13.40
180.00	19539.00	54.86	8.52	
				22.53
210.00	19362.00	64.01	8.72	
				20.96
240.00	19199.00	73.15	8.92	
				22.21
270.00	19028.00	82.30	9.12	
				21.41
300.00	18865.00	91.44	9.31	
				24.46
330.00	18681.00	100.58	9.54	
				17.92
360.00	18547.00	109.73	9.70	
				17.89
390.00	18415.00	118.87	9.87	
				19.06
420.00	18275.00	128.02	10.04	
				18.85
450.00	18138.00	137.16	10.21	
				20.13
480.00	17993.00	146.30	10.40	
				23.82
510.00	17823.00	155.45	10.61	
				24.51
540.00	17650.00	164.59	10.84	
				28.22
570.00	17456.00	173.74	11.10	
				26.57
600.00	17277.00	182.88	11.34	
				22.67
630.00	17126.00	192.02	11.55	
				25.18
660.00	16960.00	201.17	11.78	
				27.02
690.00	16784.00	210.31	12.02	
				25.77
720.00	16618.00	219.46	12.26	
				26.41
750.00	16450.00	228.60	12.50	
				27.07
780.00	16280.00	237.74	12.75	
				26.89
810.00	16113.00	246.89	12.99	
				28.65

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
840.00	15937.00	256.03	13.26	
870.00	15775.00	265.18	13.50	26.78
900.00	15570.00	274.32	13.81	34.28
930.00	15391.00	283.46	14.09	30.38
960.00	15277.00	292.61	14.27	19.54
990.00	15164.00	301.75	14.45	19.46
1020.00	15139.00	310.90	14.49	4.30

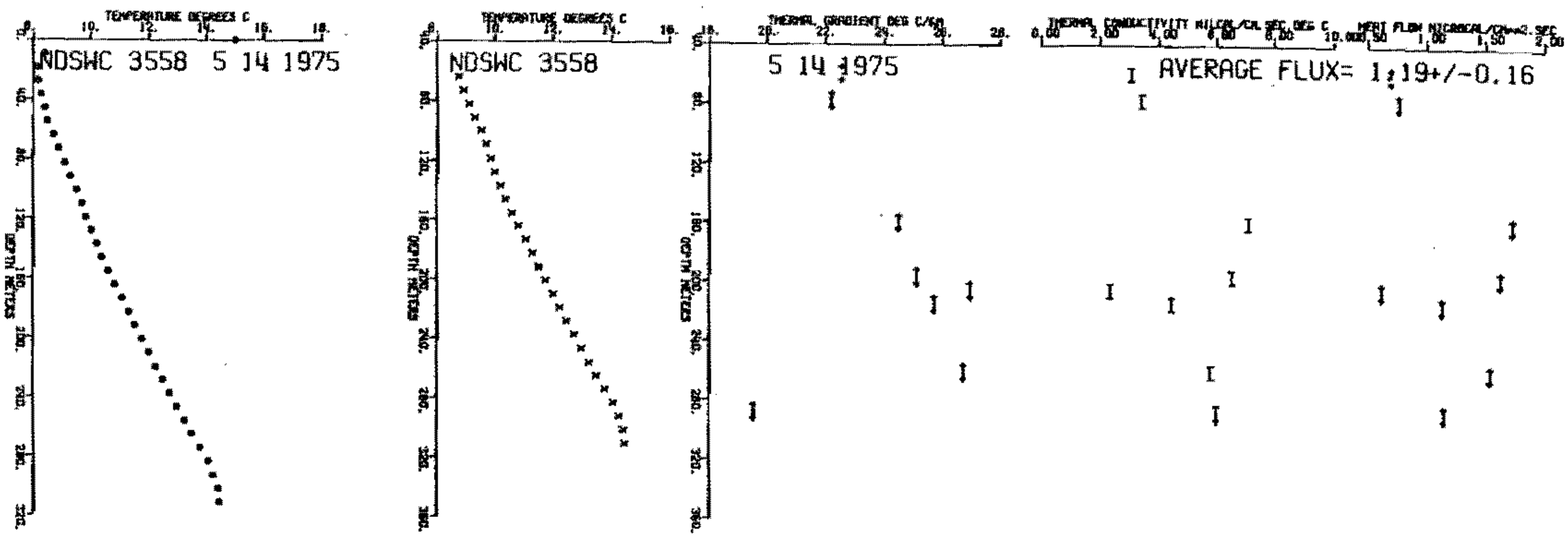
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
60.96	62.48	3.10	1.00	0.32
77.72	79.24	3.46	1.00	0.29
161.54	163.07	7.17	1.00	0.14
195.07	196.60	6.61	1.00	0.15
208.79	210.31	2.41	1.00	0.41
213.36	214.88	5.77	1.00	0.17
214.88	216.41	3.31	1.00	0.30
263.65	265.00	5.92	1.00	0.17
286.51	288.04	6.09	1.00	0.16

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
54.86	64.01	3.10	22.53	0.70
73.15	82.30	3.46	22.21	0.77
155.45	164.59	7.17	24.51	1.76
192.02	201.17	6.61	25.18	1.66
201.17	210.31	2.41	27.02	0.65
210.31	219.46	4.54	25.77	1.17
256.03	265.18	5.92	26.78	1.59
283.45	292.61	6.09	19.54	1.19

AVERAGE HEAT FLUX= 1.19 +/- 0.16 H.F.U. STD DEV 0.449

METHOD #2 FLUX= 1.02 H.F.U. # OF CONDUCTIVITIES= 9.0
UPPER DEPTH 54.86 LOWER DEPTH 292.61 METERS


TEMPERATURE DEGREES C
NDSWC 3558 5 14 1975
DEPTH METERS
NDSWC 3558
THERMAL GRADIENT DEG C/KM
5 14 1975
THERMAL CONDUCTIVITY MILCAL/CM SEC DEG C
HEAT FLOW MICROCAL/CM**2 SEC
AVERAGE FLUX= 1.19+/-0.16

NDSWC 3558 USGS OBSERVATION WATER WELL
OLIVER COUNTY 142N 84W SECTION 24 BBA
47 06' 42" NORTH LATITUDE 101 16' 27" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG= 8.15 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
7 25 1975	12 2 1967	12 1 1967	12 2 1967

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 2790
CASING SIZE 10.16CM ELEVATION 611.43 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	8480.00	0.0	28.96	
50.00	14200.00	15.24	16.02	-848.76
100.00	17200.00	30.48	11.44	-300.58
150.00	18200.00	45.72	10.13	-85.99
200.00	19393.00	60.96	8.69	-94.90
250.00	19134.00	76.20	8.99	20.01
300.00	18847.00	91.44	9.34	22.57
350.00	18590.00	106.68	9.66	21.34
400.00	18351.00	121.92	9.94	18.60
450.00	18125.00	137.16	10.23	18.60
500.00	17860.00	152.40	10.57	22.17
550.00	17568.00	167.64	10.95	24.88
600.00	17255.00	182.88	11.37	27.79
650.00	16999.00	198.12	11.72	23.18
700.00	16717.00	213.36	12.12	25.98
750.00	16422.00	228.60	12.54	27.76
800.00	16145.00	243.84	12.95	26.59
850.00	15870.00	259.08	13.36	26.95
900.00	15537.00	274.32	13.86	33.32
950.00	15299.00	289.56	14.24	24.37
1000.00	15203.00	304.80	14.39	9.93

NDSWC 3558 USGS OBSERVATION WATER WELL

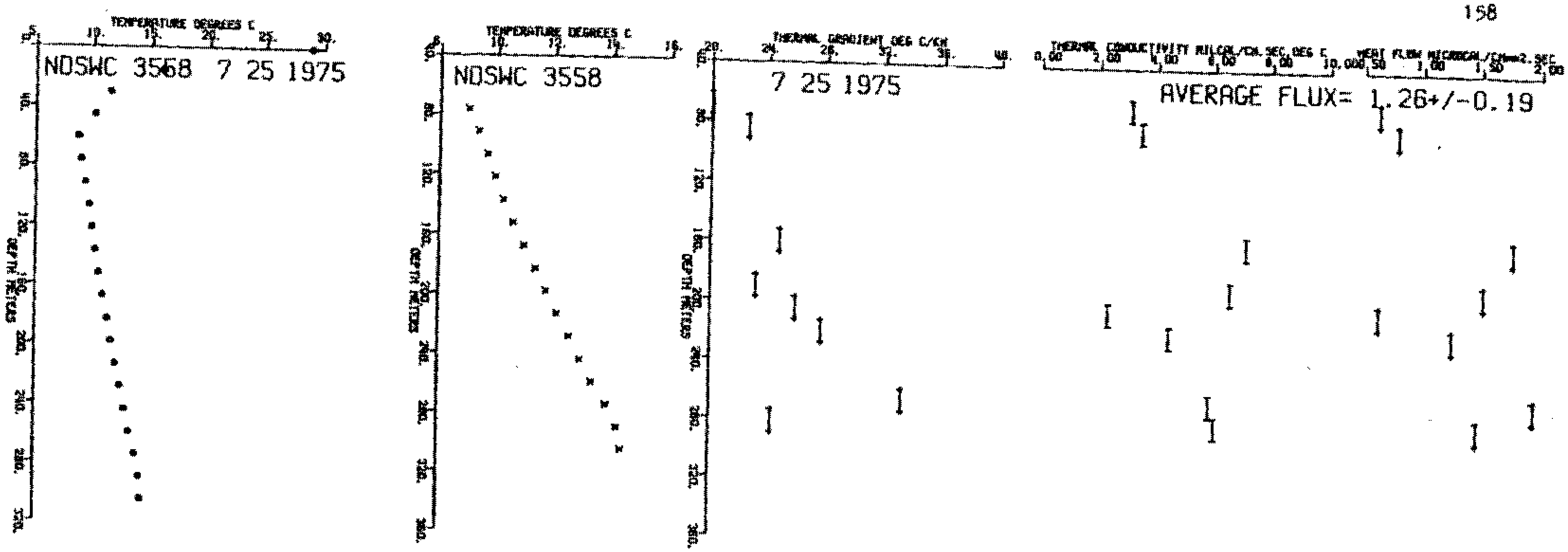
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
60.96	62.48	3.10	1.00	0.32
77.72	79.24	3.46	1.00	0.29
161.54	163.07	7.17	1.00	0.14
195.07	196.60	6.61	1.00	0.15
208.79	210.31	2.41	1.00	0.41
213.36	214.88	5.77	1.00	0.17
214.88	216.41	3.31	1.00	0.30
263.65	265.00	5.92	1.00	0.17
286.51	288.04	6.09	1.00	0.16

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
60.96	76.20	3.10	20.01	0.62
76.20	91.44	3.46	22.57	0.78
152.40	167.64	7.17	24.88	1.78
182.88	198.12	6.61	23.18	1.53
198.12	213.36	2.41	25.98	0.63
213.36	228.60	4.54	27.76	1.26
259.08	274.32	5.92	33.32	1.97
274.32	289.56	6.09	24.37	1.48

AVERAGE HEAT FLUX= 1.26 +/- 0.19 H.F.U. STD DEV 0.527

METHOD #2 FLUX= 1.03 H.F.U. # OF CONDUCTIVITIES= 9.0
UPPER DEPTH 60.96 LOWER DEPTH 289.56 METERS


NDSWC 3568 7 25 1975
TEMPERATURE DEGREES C
DEPTH METERS
NDSWC 3558
TEMPERATURE DEGREES C
DEPTH METERS
7 25 1975
THERMAL GRADIENT DEG C/KM
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.26+/-0.19

NDGS 2894 BROWN .ET. AL. US GOVT. SEISMIC SITE
GOLDEN VALLEY COUNTY 142N 102W SECTION 24 NE NE
47 6' 34" NORTH LATITUDE 103 40' 4" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=18.30 HOURS.MINUTES
DATE LOGGED DATE WELL COMPLETED DATE SPUDDED DATE OF DRILLING TERMINATION
6 2 1976 9 29 1964 8 10 1964 9 25 1964
DRILLING PERIOD= 46 DAYS DAYS SINCE 1ST PERIOD= 4265
CASING SIZE 17.78CM ELEVATION 815.64 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	9200.00	0.0	24.62	
50.00	16640.00	15.24	9.94	-963.36
104.80	17590.00	31.94	8.64	-77.70
160.00	17340.00	48.77	8.98	19.82
200.10	17125.00	60.99	9.27	23.81
250.10	16847.00	76.23	9.65	25.15
301.10	16570.00	91.78	10.04	25.05
350.00	16315.00	106.68	10.40	24.49
400.00	16065.00	121.92	10.77	23.90
450.00	15725.00	137.16	11.28	33.75
500.00	15311.00	152.40	11.93	42.58
530.70	15140.00	161.76	12.21	29.30
560.20	15000.00	170.75	12.43	25.22
600.10	14825.00	182.91	12.72	23.63
650.30	14594.00	198.21	13.11	25.21
700.30	14270.00	213.45	13.66	36.27
740.30	14011.00	225.64	14.11	37.11
767.20	13875.00	233.84	14.35	29.51
797.20	13708.00	242.99	14.65	32.84
850.30	13465.00	259.17	15.09	27.23
900.10	13220.00	274.35	15.54	29.56
950.00	12942.00	289.56	16.06	34.24
1000.20	12700.00	304.86	16.53	30.33
1050.40	12503.00	320.16	16.91	25.18
1097.70	12260.00	334.58	17.40	33.70
1127.60	12115.00	343.69	17.69	32.33
1160.00	11950.00	353.57	18.03	34.54
1200.20	11725.00	365.82	18.51	38.67
				45.76

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
1250.00	11404.00	381.00	19.20	
				34.41
1300.10	11168.00	396.27	19.73	
				30.42
1350.50	10962.00	411.63	20.20	
				29.44
1397.00	10780.00	425.81	20.61	
				28.19
1427.60	10667.00	435.13	20.88	
				43.63
1460.00	10485.00	445.01	21.31	
				35.16
1500.10	10307.00	457.23	21.74	
				31.91
1550.60	10108.00	472.62	22.23	
				38.30
1600.00	9880.00	487.68	22.80	
				28.29
1650.00	9713.50	502.92	23.24	
				26.00
1700.10	9563.00	518.19	23.63	
				27.42
1750.00	9408.00	533.40	24.05	
				27.68
1800.70	9252.00	548.85	24.48	
				27.26
1847.10	9114.00	563.00	24.86	
				25.71
1877.10	9031.00	572.14	25.10	
				33.22
1925.30	8861.50	586.83	25.59	
				36.09
1987.00	8632.00	605.64	26.26	
				35.61
2017.10	8524.00	614.81	26.59	
				36.77
2050.30	8403.00	624.93	26.96	
				39.22
2100.50	8212.00	640.23	27.56	
				39.87
2150.00	8025.50	655.32	28.17	
				41.94
2200.10	7831.50	670.59	28.81	
				43.82
2227.30	7723.00	678.88	29.17	
				39.68
2257.40	7616.00	688.06	29.53	
				43.63
2300.10	7452.50	701.07	30.10	
				42.95
2350.60	7267.50	716.46	30.76	
				43.60
2400.00	7089.00	731.52	31.42	
				44.93
2450.10	6908.00	746.79	32.10	
				45.70
2500.30	6729.00	762.09	32.80	
				44.35
2550.00	6562.00	777.24	33.48	
				44.04
2617.00	6346.00	797.66	34.38	
				49.96
2647.30	6238.50	806.90	34.84	
				44.50
2700.00	6076.00	822.96	35.55	
				44.40

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
2750.10	5927.00	838.23	36.23	48.34
2800.50	5769.00	853.59	36.97	47.45
2850.10	5621.00	868.71	37.69	48.43
2900.00	5473.70	883.92	38.43	47.14
2950.50	5333.30	899.31	39.15	48.22
3000.10	5196.60	914.43	39.88	43.41
3067.10	5036.00	934.85	40.77	42.93
3097.70	4965.30	944.18	41.17	40.87
3150.40	4852.00	960.24	41.82	39.42
3200.30	4751.20	975.45	42.42	43.16
3250.00	4644.00	990.60	43.08	48.14
3300.10	4527.00	1005.87	43.81	51.82
3350.10	4404.90	1021.11	44.60	54.78
3400.50	4278.30	1036.47	45.44	52.01
3450.20	4163.70	1051.62	46.23	51.11
3517.10	4017.50	1072.01	47.27	41.78
3547.20	3965.30	1081.19	47.66	35.24
3600.00	3889.50	1097.28	48.22	35.47
3650.50	3818.20	1112.67	48.77	36.12
3727.00	3710.80	1135.99	49.61	39.54
3757.00	3665.80	1145.13	49.97	46.56
3800.30	3590.70	1158.33	50.59	47.90
3850.30	3503.90	1173.57	51.32	45.66
3900.10	3423.80	1188.75	52.01	45.54
3950.60	3344.90	1204.14	52.71	42.31
4000.10	3275.00	1219.23	53.35	37.99
4050.30	3212.70	1234.53	53.93	39.42
4100.00	3149.00	1249.68	54.53	38.72
4150.00	3087.50	1264.92	55.12	42.74
4200.00	3021.20	1280.16	55.77	42.74
4237.20	2973.00	1291.50	56.26	40.93
4267.20	2936.40	1300.64	56.63	43.07
4300.10	2894.80	1310.67	57.06	48.08

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
4350.30	2825.60	1325.97	57.80	44.33
4387.90	2778.90	1337.43	58.31	42.19
4417.00	2745.50	1346.30	58.68	35.07
4450.00	2714.60	1356.36	59.03	41.11
4500.00	2660.70	1371.60	59.66	44.11
4537.10	2618.70	1382.91	60.16	44.68
4567.70	2584.20	1392.23	60.57	47.96
4601.00	2544.60	1402.38	61.06	45.93
4650.00	2490.00	1417.32	61.75	48.80
4700.00	2432.40	1432.56	62.49	56.50
4750.10	2367.50	1447.83	63.35	43.74
4800.20	2318.70	1463.10	64.02	42.42
4850.30	2272.50	1478.37	64.67	48.48
4867.20	2255.00	1483.52	64.92	52.73
4897.20	2221.60	1492.67	65.40	51.56
4950.00	2165.50	1508.76	66.23	49.60
4997.40	2118.40	1523.21	66.95	46.09
5007.20	2109.50	1526.19	67.09	54.74
5050.00	2064.00	1539.24	67.80	51.87
5100.00	2015.00	1554.48	68.59	59.98
5127.10	1985.00	1562.74	69.09	65.66
5138.70	1971.10	1566.28	69.32	63.56
5157.20	1949.80	1571.91	69.68	61.16
5167.30	1938.60	1574.99	69.86	56.43
5187.10	1918.60	1581.03	70.20	75.71
5197.00	1905.30	1584.05	70.43	58.51
5237.10	1864.40	1596.27	71.15	73.69
5247.00	1851.90	1599.29	71.37	45.13
5300.00	1811.60	1615.44	72.10	43.70
5350.00	1775.70	1630.68	72.77	35.57
5400.20	1747.00	1645.98	73.31	27.94
5450.00	1725.00	1661.16	73.73	29.78
5477.00	1712.40	1669.39	73.98	41.15

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
5487.20	1705.90	1672.50	74.11	
5537.20	1667.00	1687.74	74.88	50.83
5547.70	1658.30	1690.94	75.06	55.08
5600.30	1620.00	1706.97	75.85	49.26
5650.10	1583.50	1722.15	76.62	50.94
5700.00	1553.00	1737.36	77.28	43.58
5800.00	1521.00	1767.84	78.00	23.36
5817.00	1520.00	1773.02	78.02	4.33
5828.50	1519.50	1776.53	78.03	3.27
5875.10	1507.60	1790.73	78.30	18.98
5937.40	1485.70	1809.72	78.80	26.51
5948.60	1475.00	1813.13	79.05	72.95
6007.00	1466.70	1830.93	79.25	10.94
6017.20	1460.10	1834.04	79.40	50.03
6075.30	1451.70	1851.75	79.60	11.26
6125.00	1437.50	1866.90	79.94	22.43
6177.00	1414.80	1882.75	80.49	34.77
6187.10	1408.80	1885.83	80.64	47.99
6250.00	1381.20	1905.00	81.33	35.87
6300.10	1358.80	1920.27	81.90	37.40
6350.00	1340.00	1935.48	82.39	32.05
6427.10	1320.50	1958.98	82.90	21.90
6437.10	1308.50	1962.03	83.22	105.33
6475.00	1283.80	1973.58	83.89	58.20
6500.00	1273.60	1981.20	84.18	37.07

NDGS 2894 BROWN .ET. AL. US GOVT. SEISMIC SITE

DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
140.00	151.00	4.10	1.00	0.24
153.48	160.62	4.18	1.00	0.24
234.00	242.00	7.92	1.00	0.13
335.00	343.50	3.98	1.00	0.25
550.00	560.00	4.00	1.00	0.25
563.00	572.10	4.06	1.00	0.25
1136.00	1145.00	4.24	1.00	0.24
1568.00	1571.00	4.00	1.00	0.25
1572.00	1574.00	4.11	1.00	0.24
1585.00	1590.00	3.39	1.00	0.29
1810.00	1812.65	3.62	1.00	0.28
1882.75	1885.80	4.73	1.00	0.21

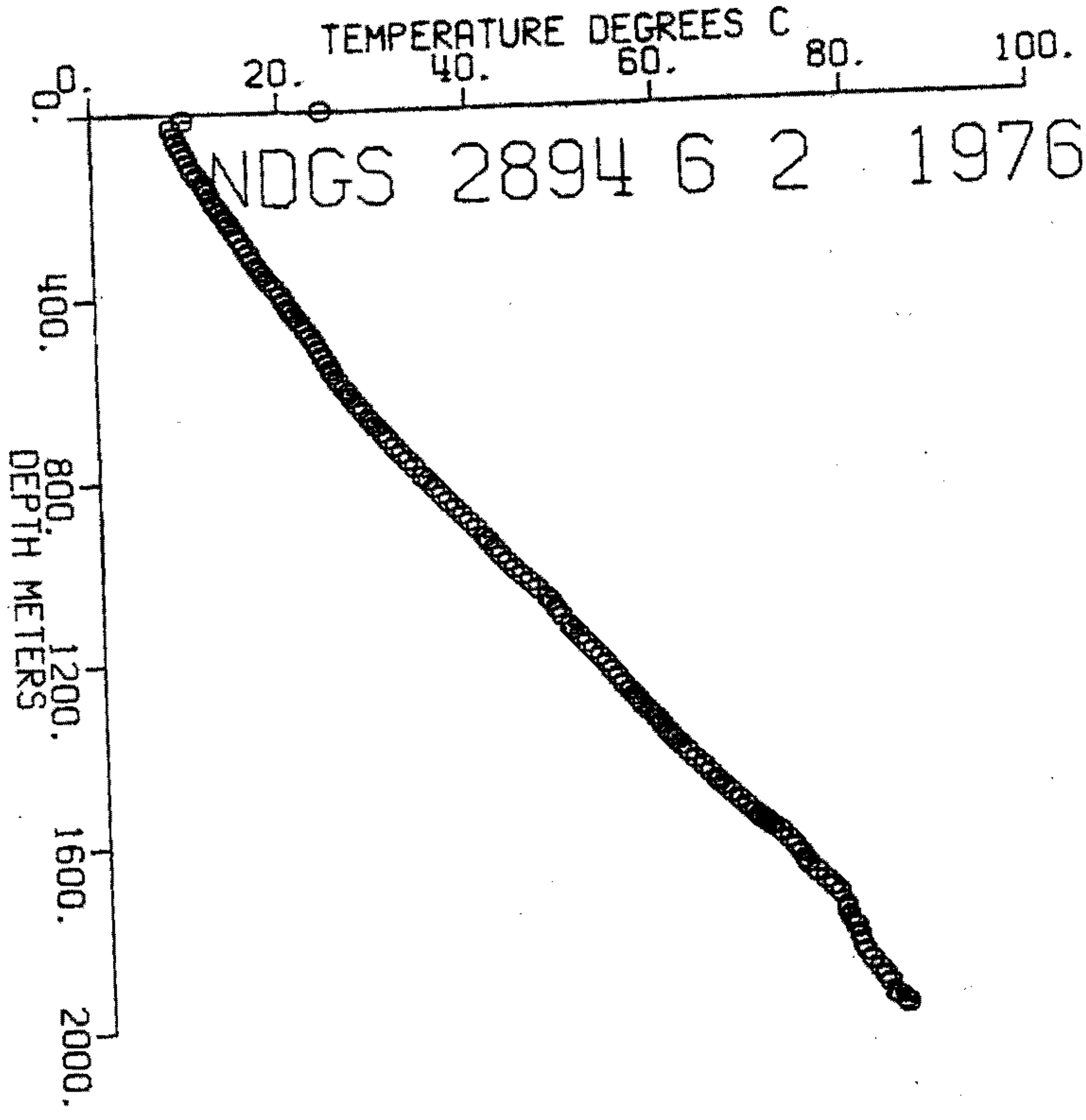
HEAT FLUX CALCULATION INTERVAL METHOD

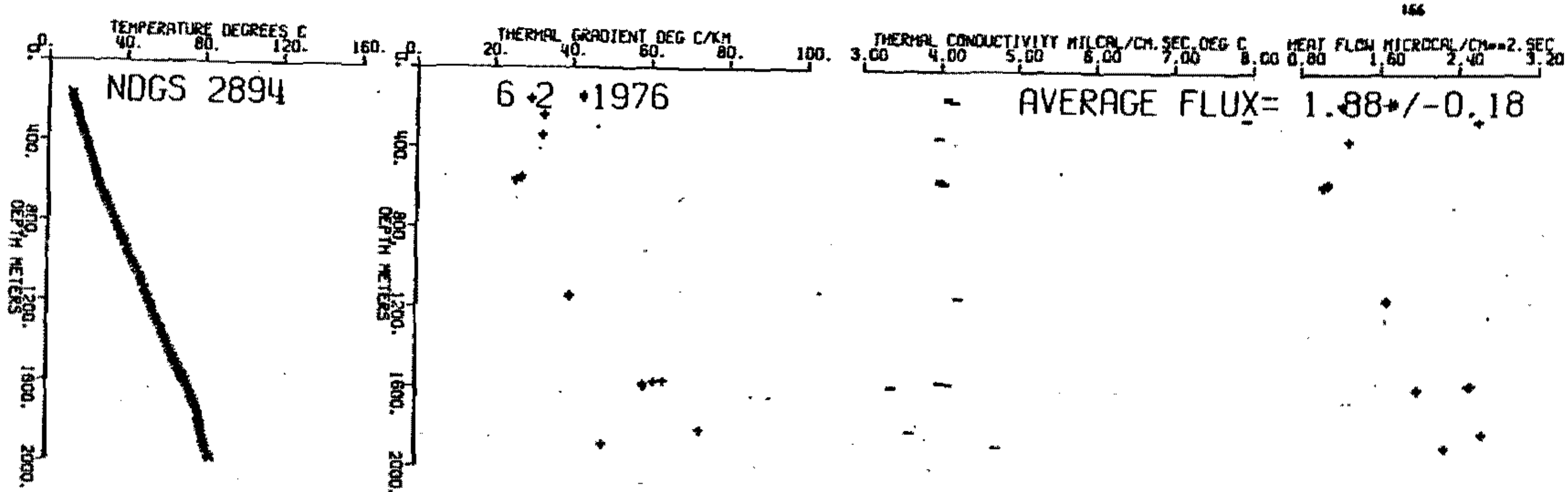
DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
137.16	152.40	4.10	42.58	1.75
152.40	161.76	4.18	29.30	1.22
233.84	242.99	7.92	32.84	2.60
334.58	343.69	3.98	32.33	1.29
548.85	563.00	4.00	27.26	1.09
563.00	572.14	4.06	25.71	1.04
1135.99	1145.13	4.24	39.54	1.68
1566.28	1571.91	4.00	63.56	2.54
1571.91	1574.99	4.11	61.16	2.51
1584.05	1596.27	3.39	58.51	1.98
1809.72	1813.13	3.62	72.95	2.64
1882.75	1885.83	4.73	47.99	2.27

AVERAGE HEAT FLUX= 1.88 +/- 0.18 H.F.U. STD DEV 0.623

METHOD #2 FLUX= 1.66 H.F.U. # OF CONDUCTIVITIES=11.0
UPPER DEPTH 152.40 LOWER DEPTH 1885.83 METERS

165


TEMPERATURE DEGREES C
0.
20.
40.
60.
80.
100.
NDGS 2894 6 2 1976
0.
400.
800.
1200.
1600.
2000.
DEPTH METERS


NDGS 2894
6-2-1976
AVERAGE FLUX= 1.88+/-0.18
TEMPERATURE DEGREES C
THERMAL GRADIENT DEG C/KM
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
DEPTH METERS
DEPTH METERS

NDGS 2894 BROWN .ET. AL. US GOVT. SEISMIC SITE
GOLDEN VALLEY COUNTY 142N 102W SECTION 24 NE NE
47 6' 34" NORTH LATITUDE 103 40' 4" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=18.30 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
6 2 1976	9 29 1964	8 10 1964	9 25 1964

DRILLING PERIOD= 46 DAYS DAYS SINCE 1ST PERIOD= 4265
CASING SIZE 17.78CM ELEVATION 815.64 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	9200.00	0.0	24.62	
				-963.36
50.00	16640.00	15.24	9.94	
				-77.70
104.80	17590.00	31.94	8.64	
				19.82
160.00	17340.00	48.77	8.98	
				23.81
200.10	17125.00	60.99	9.27	
				25.15
250.10	16847.00	76.23	9.65	
				25.05
301.10	16570.00	91.78	10.04	
				24.49
350.00	16315.00	106.68	10.40	
				23.90
400.00	16065.00	121.92	10.77	
				33.75
450.00	15725.00	137.16	11.28	
				42.58
500.00	15311.00	152.40	11.93	
				29.30
530.70	15140.00	161.76	12.21	
				25.22
560.20	15000.00	170.75	12.43	
				23.63
600.10	14825.00	182.91	12.72	
				25.21
650.30	14594.00	198.21	13.11	
				36.27
700.30	14270.00	213.45	13.66	
				37.11
740.30	14011.00	225.64	14.11	
				29.51
767.20	13875.00	233.84	14.35	
				32.84
797.20	13708.00	242.99	14.65	
				27.23
850.30	13465.00	259.17	15.09	
				29.56
900.10	13220.00	274.35	15.54	
				34.24
950.00	12942.00	289.56	16.06	
				30.33
1000.20	12700.00	304.86	16.53	
				25.18
1050.40	12503.00	320.16	16.91	
				33.70
1097.70	12260.00	334.58	17.40	
				32.33
1127.60	12115.00	343.69	17.69	
				34.54
1160.00	11950.00	353.57	18.03	
				38.67
1200.20	11725.00	365.82	18.51	
				45.76

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
1250.00	11404.00	381.00	19.20	
				34.41
1300.10	11168.00	396.27	19.73	
				30.42
1350.50	10962.00	411.63	20.20	
				29.44
1397.00	10780.00	425.81	20.61	
				28.19
1427.60	10667.00	435.13	20.88	
				43.63
1460.00	10485.00	445.01	21.31	
				35.16
1500.10	10307.00	457.23	21.74	
				31.91
1550.60	10108.00	472.62	22.23	
				38.30
1600.00	9880.00	487.68	22.80	
				28.29
1650.00	9713.50	502.92	23.24	
				26.00
1700.10	9563.00	518.19	23.63	
				27.42
1750.00	9408.00	533.40	24.05	
				27.68
1800.70	9252.00	548.85	24.48	
				27.26
1847.10	9114.00	563.00	24.86	
				25.71
1877.10	9031.00	572.14	25.10	
				33.22
1925.30	8861.50	586.83	25.59	
				36.09
1987.00	8632.00	605.64	26.26	
				35.61
2017.10	8524.00	614.81	26.59	
				36.77
2050.30	8403.00	624.93	26.96	
				39.22
2100.50	8212.00	640.23	27.56	
				39.87
2150.00	8025.50	655.32	28.17	
				41.94
2200.10	7831.50	670.59	28.81	
				43.82
2227.30	7723.00	678.88	29.17	
				39.68
2257.40	7616.00	688.06	29.53	
				43.63
2300.10	7452.50	701.07	30.10	
				42.95
2350.60	7267.50	716.46	30.76	
				43.60
2400.00	7089.00	731.52	31.42	
				44.93
2450.10	6908.00	746.79	32.10	
				45.70
2500.30	6729.00	762.09	32.80	
				44.35
2550.00	6562.00	777.24	33.48	
				44.04
2617.00	6346.00	797.66	34.38	
				49.96
2647.30	6238.50	806.90	34.84	
				44.50
2700.00	6076.00	822.96	35.55	
				44.40

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
2750.10	5927.00	838.23	36.23	48.34
2800.50	5769.00	853.59	36.97	47.45
2850.10	5621.00	868.71	37.69	48.43
2900.00	5473.70	883.92	38.43	47.14
2950.50	5333.30	899.31	39.15	48.22
3000.10	5196.60	914.43	39.88	43.41
3067.10	5036.00	934.85	40.77	42.93
3097.70	4965.30	944.18	41.17	40.87
3150.40	4852.00	960.24	41.82	39.42
3200.30	4751.20	975.45	42.42	43.16
3250.00	4644.00	990.60	43.08	48.14
3300.10	4527.00	1005.87	43.81	51.82
3350.10	4404.90	1021.11	44.60	54.78
3400.50	4278.30	1036.47	45.44	52.01
3450.20	4163.70	1051.62	46.23	51.11
3517.10	4017.50	1072.01	47.27	41.78
3547.20	3965.30	1081.19	47.66	35.24
3600.00	3889.50	1097.28	48.22	35.47
3650.50	3818.20	1112.67	48.77	36.12
3727.00	3710.80	1135.99	49.61	39.54
3757.00	3665.80	1145.13	49.97	46.56
3800.30	3590.70	1158.33	50.59	47.90
3850.30	3503.90	1173.57	51.32	45.66
3900.10	3423.80	1188.75	52.01	45.54
3950.60	3344.90	1204.14	52.71	42.31
4000.10	3275.00	1219.23	53.35	37.99
4050.30	3212.70	1234.53	53.93	39.42
4100.00	3149.00	1249.68	54.53	38.72
4150.00	3087.50	1264.92	55.12	42.74
4200.00	3021.20	1280.16	55.77	42.74
4237.20	2973.00	1291.50	56.26	40.93
4267.20	2936.40	1300.64	56.63	43.07
4300.10	2894.80	1310.67	57.06	48.08

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
4350.30	2825.60	1325.97	57.80	44.33
4387.90	2778.90	1337.43	58.31	42.19
4417.00	2745.50	1346.30	58.68	35.07
4450.00	2714.60	1356.36	59.03	41.11
4500.00	2660.70	1371.60	59.66	44.11
4537.10	2618.70	1382.91	60.16	44.68
4567.70	2584.20	1392.23	60.57	47.96
4601.00	2544.60	1402.38	61.06	45.93
4650.00	2490.00	1417.32	61.75	48.80
4700.00	2432.40	1432.56	62.49	56.50
4750.10	2367.50	1447.83	63.35	43.74
4800.20	2318.70	1463.10	64.02	42.42
4850.30	2272.50	1478.37	64.67	48.48
4867.20	2255.00	1483.52	64.92	52.73
4897.20	2221.60	1492.67	65.40	51.56
4950.00	2165.50	1508.76	66.23	49.60
4997.40	2118.40	1523.21	66.95	46.09
5007.20	2109.50	1526.19	67.09	54.74
5050.00	2064.00	1539.24	67.80	51.87
5100.00	2015.00	1554.48	68.59	59.98
5127.10	1985.00	1562.74	69.09	65.66
5138.70	1971.10	1566.28	69.32	63.56
5157.20	1949.80	1571.91	69.68	61.16
5167.30	1938.60	1574.99	69.86	56.43
5187.10	1918.60	1581.03	70.20	75.71
5197.00	1905.30	1584.05	70.43	58.51
5237.10	1864.40	1596.27	71.15	73.69
5247.00	1851.90	1599.29	71.37	45.13
5300.00	1811.60	1615.44	72.10	43.70
5350.00	1775.70	1630.68	72.77	35.57
5400.20	1747.00	1645.98	73.31	27.94
5450.00	1725.00	1661.16	73.73	29.78
5477.00	1712.40	1669.39	73.98	41.15

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
5487.20	1705.90	1672.50	74.11	50.83
5537.20	1667.00	1687.74	74.88	55.08
5547.70	1658.30	1690.94	75.06	49.26
5600.30	1620.00	1706.97	75.85	50.94
5650.10	1583.50	1722.15	76.62	43.58
5700.00	1553.00	1737.36	77.28	23.36
5800.00	1521.00	1767.84	78.00	4.33
5817.00	1520.00	1773.02	78.02	3.27
5828.50	1519.50	1776.53	78.03	18.98
5875.10	1507.60	1790.73	78.30	26.51
5937.40	1485.70	1809.72	78.80	72.95
5948.60	1475.00	1813.13	79.05	10.94
6007.00	1466.70	1830.93	79.25	50.03
6017.20	1460.10	1834.04	79.40	11.26
6075.30	1451.70	1851.75	79.60	22.43
6125.00	1437.50	1866.90	79.94	34.77
6177.00	1414.80	1882.75	80.49	47.99
6187.10	1408.80	1885.83	80.64	35.87
6250.00	1381.20	1905.00	81.33	37.40
6300.10	1358.80	1920.27	81.90	32.05
6350.00	1340.00	1935.48	82.39	21.90
6427.10	1320.50	1958.98	82.90	105.33
6437.10	1308.50	1962.03	83.22	58.20
6475.00	1283.80	1973.58	83.89	37.07
6500.00	1273.60	1981.20	84.18	

NDGS 2894 BROWN .ET. AL. US GOVT. SEISMIC SITE

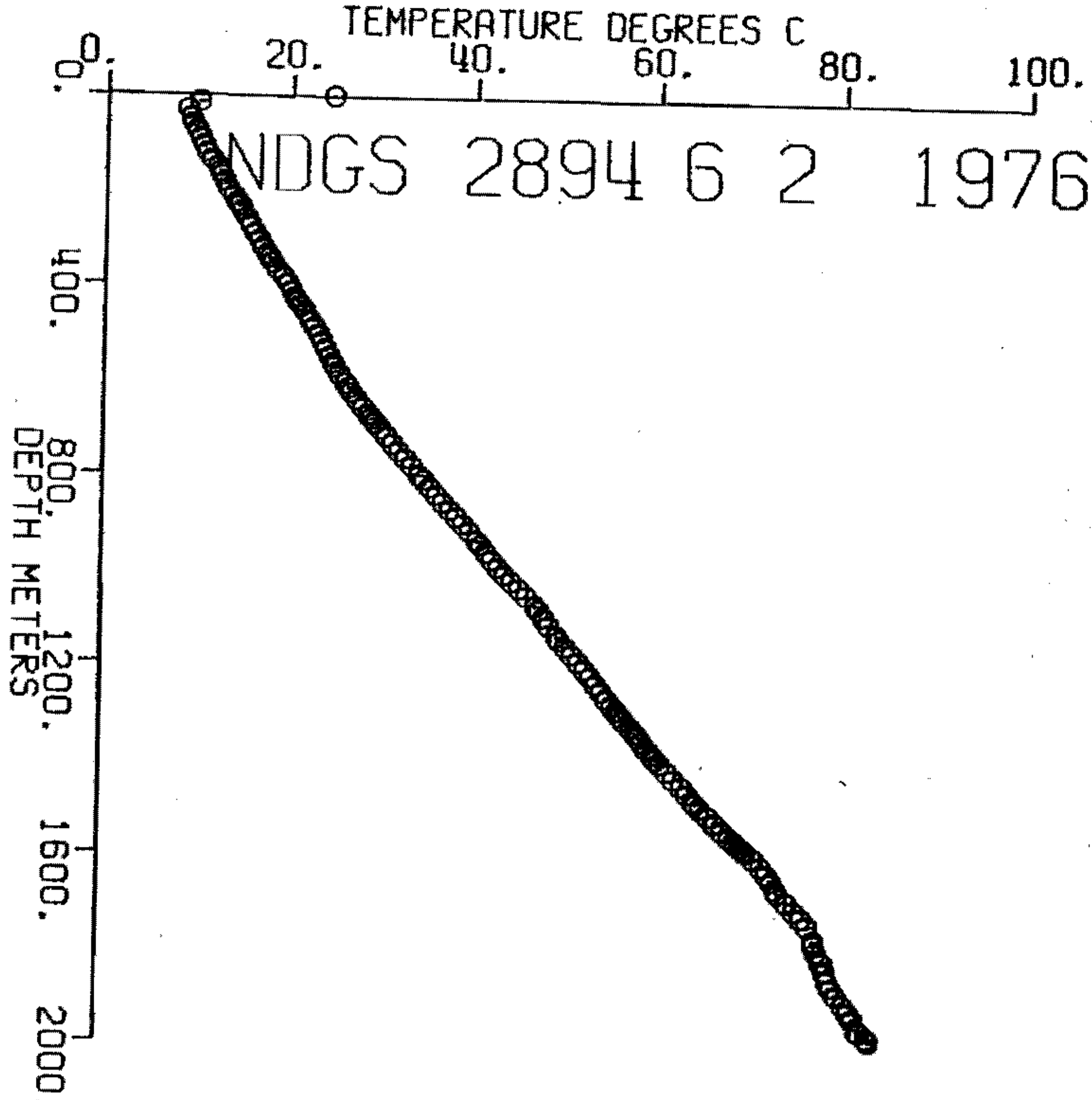
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
140.00	151.00	4.10	1.00	0.24
153.48	160.62	4.18	1.00	0.24
234.00	242.00	5.88	1.00	0.17
335.00	343.50	3.98	1.00	0.25
550.00	560.00	4.40	1.00	0.23
563.00	572.10	4.56	1.00	0.22
1136.00	1145.00	4.34	1.00	0.23
1568.00	1571.00	2.37	1.00	0.42
1572.00	1574.00	2.50	1.00	0.40
1585.00	1590.00	2.68	1.00	0.37
1810.00	1812.65	2.22	1.00	0.45
1882.75	1885.80	3.28	1.00	0.30

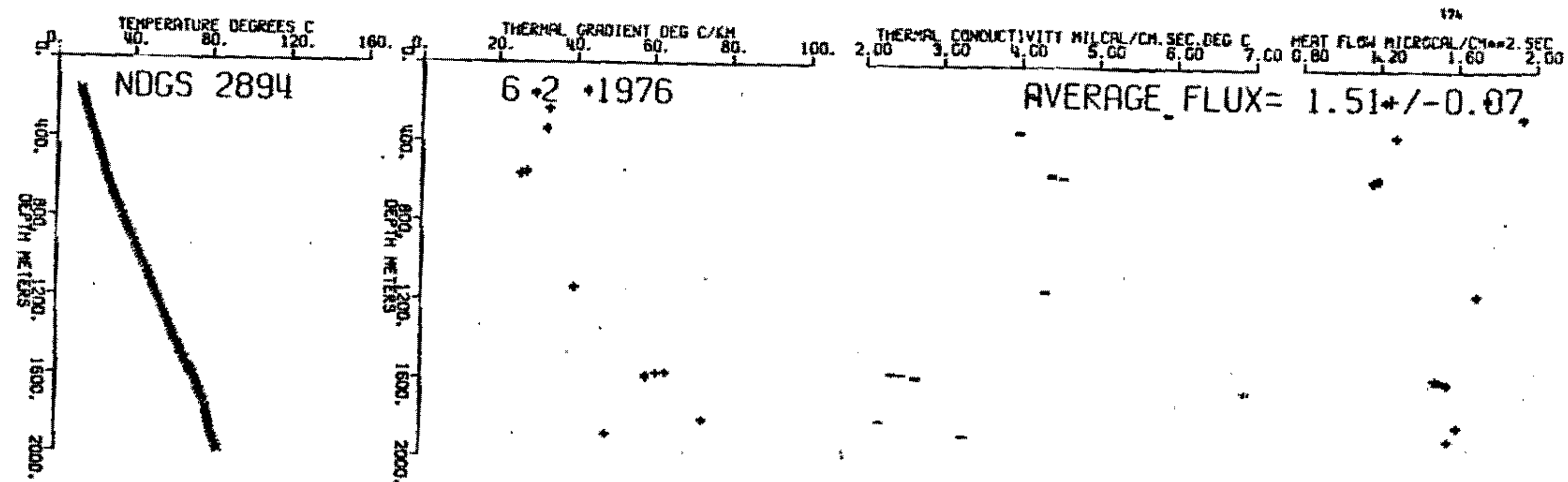
HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
137.16	152.40	4.10	42.58	1.75
152.40	161.76	4.18	29.30	1.22
233.84	242.99	5.88	32.84	1.93
334.58	343.69	3.98	32.33	1.29
548.85	563.00	4.40	27.26	1.20
563.00	572.14	4.56	25.71	1.17
1135.99	1145.13	4.34	39.54	1.72
1566.28	1571.91	2.37	63.56	1.51
1571.91	1574.99	2.50	61.16	1.53
1584.05	1596.27	2.68	58.51	1.57
1809.72	1813.13	2.22	72.95	1.62
1882.75	1885.83	3.28	47.99	1.57

AVERAGE HEAT FLUX= 1.51 +/- 0.07 H.F.U. STD DEV 0.241

METHOD #2 FLUX= 1.33 H.F.U. # OF CONDUCTIVITIES=11.0
UPPER DEPTH 152.40 LOWER DEPTH 1885.83 METERS


TEMPERATURE DEGREES C
0.
20.
40.
60.
80.
100.
NDGS 2894 6 2 1976
0.
400.
800.
1200.
1600.
2000.
DEPTH METERS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TEMPERATURE DEGREES C
THERMAL GRADIENT DEG C/KM
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
DEPTH METERS
NDGS 2894
6-2-1976
AVERAGE FLUX= 1.51+/-0.07

NDGS 2894 BROWN .ET. AL. US GOVT. SEISMIC SITE
GOLDEN VALLEY COUNTY 142N 102W SECTION 24 NE NE
47 6' 34" NORTH LATITUDE 103 40' 4" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=10.35 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
3 27 1976	9 29 1964	8 10 1964	9 25 1964

DRILLING PERIOD= 46 DAYS DAYS SINCE 1ST PERIOD= 4198
CASING SIZE 17.78CM ELEVATION 815.64 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	20600.00	0.0	7.33	
				54.07
100.00	19150.00	30.48	8.97	
				23.78
200.00	18550.00	60.96	9.70	
				17.09
303.00	18120.00	92.35	10.23	
				26.85
401.00	17500.00	122.22	11.04	
				38.07
500.00	16670.00	152.40	12.19	
				24.34
600.00	16158.00	182.88	12.93	
				35.20
700.00	15450.00	213.36	14.00	
				31.67
800.00	14840.00	243.84	14.97	
				28.77
900.00	14308.00	274.32	15.84	
				30.98
1000.00	13760.00	304.80	16.79	
				31.94
1101.00	13215.00	335.58	17.77	
				42.62
1200.00	12540.00	365.76	19.06	
				35.70
1300.00	12000.00	396.24	20.14	
				38.98
1400.00	11440.00	426.72	21.33	
				36.19
1487.00	11010.00	453.24	22.29	

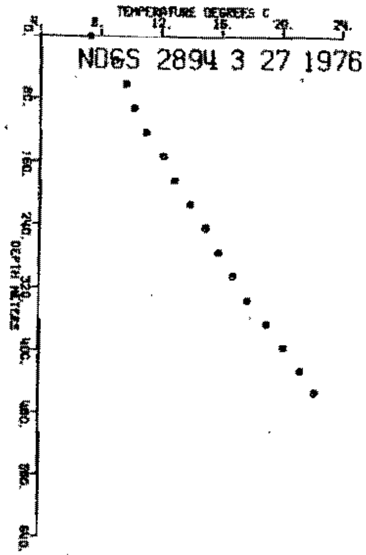
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
140.00	151.00	4.10	1.00	0.24
153.00	160.62	4.18	1.00	0.24
234.78	242.92	5.88	1.00	0.17
334.36	343.50	3.98	1.00	0.25

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
122.22	152.40	4.10	38.07	1.56
152.40	182.88	4.18	24.34	1.02
213.36	243.84	5.88	31.67	1.86
304.80	335.58	3.98	31.94	1.27

AVERAGE HEAT FLUX= 1.43 +/- 0.18 H.F.U. STD DEV 0.365

METHOD #2 FLUX= 1.46 H.F.U. # OF CONDUCTIVITIES= 3.0
UPPER DEPTH 152.40 LOWER DEPTH 365.76 METERS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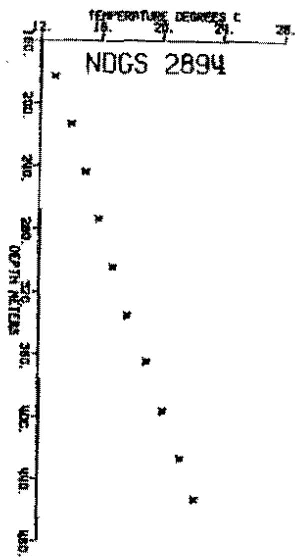
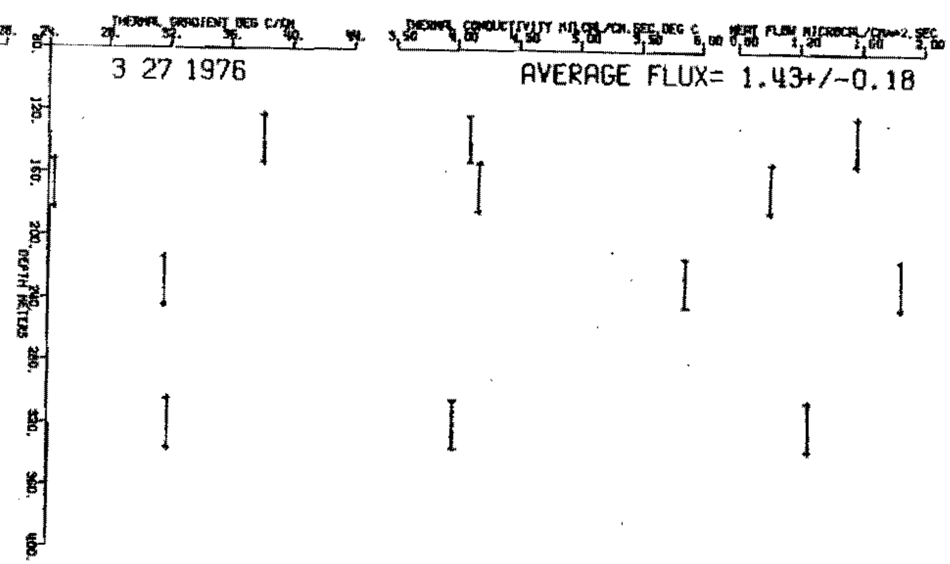
NDGS 2894 3 27 1976
DEPTH METERS


TEMPERATURE DEGREES C
NDGS 2894
DEPTH METERS


THERMAL GRADIENT DEG C/CM
3 27 1976
DEPTH METERS
THERMAL CONDUCTIVITY MILLICAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.43+/-0.18

NDSWC 4812 USGS OBSERVATION WATER WELL
GOLDEN VALLEY COUNTY 143N 105W SECTION 33 BDD
47 10' 1'' NORTH LATITUDE 103 59' 58'' WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=18.05 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
3 27 1976	7 30 1975	7 15 1975	7 30 1975

DRILLING PERIOD= 15 DAYS DAYS SINCE 1ST PERIOD= 240
CASING SIZE 5.08CM ELEVATION 726.95 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	13125.00	0.0	17.94	
				-722.12
50.00	20965.00	15.24	6.93	
				62.83
100.00	20090.00	30.48	7.89	
				57.59
151.00	19310.00	46.02	8.78	
				57.05
200.00	18600.00	60.96	9.64	
				28.50
250.00	18250.00	76.20	10.07	
				12.40
300.00	18100.00	91.44	10.26	
				42.23
350.00	17600.00	106.68	10.90	
				32.34
400.00	17235.00	121.92	11.40	
				41.06
450.00	16785.00	137.16	12.02	
				32.84
500.00	16435.00	152.40	12.52	
				39.01
550.00	16030.00	167.64	13.12	
				41.20
600.00	15615.00	182.88	13.74	
				42.48
650.00	15200.00	198.12	14.39	
				28.08
700.00	14930.00	213.36	14.82	
				37.85
750.00	14575.00	228.60	15.40	
				33.40
800.00	14270.00	243.84	15.91	
				27.43
850.00	14025.00	259.08	16.32	
				23.39
900.00	13820.00	274.32	16.68	
				31.43
950.00	13550.00	289.56	17.16	
				17.78
960.00	13520.00	292.61	17.21	

NDSWC 4812 USGS OBSERVATION WATER WELL

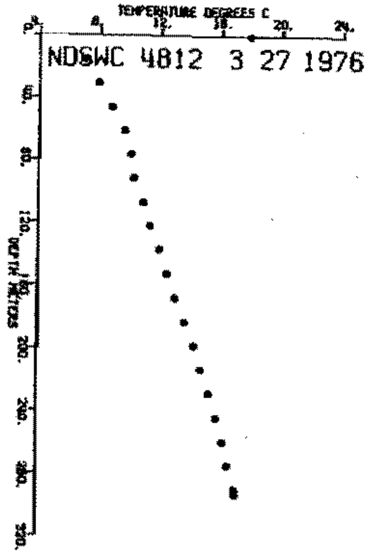
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
152.40	153.92	3.89	1.00	0.26
155.44	156.97	3.83	1.00	0.26
158.49	160.02	7.09	1.00	0.14
161.54	163.06	7.01	1.00	0.14
164.59	166.11	3.66	1.00	0.27
216.41	217.93	3.84	1.00	0.26
222.50	224.03	3.73	1.00	0.27
225.55	227.08	5.21	1.00	0.19
237.74	239.27	3.80	1.00	0.26

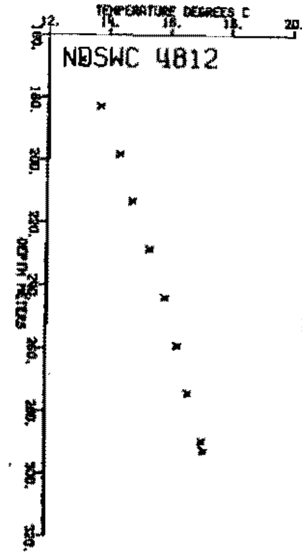
HEAT FLUX CALCULATION INTERVAL METHOD

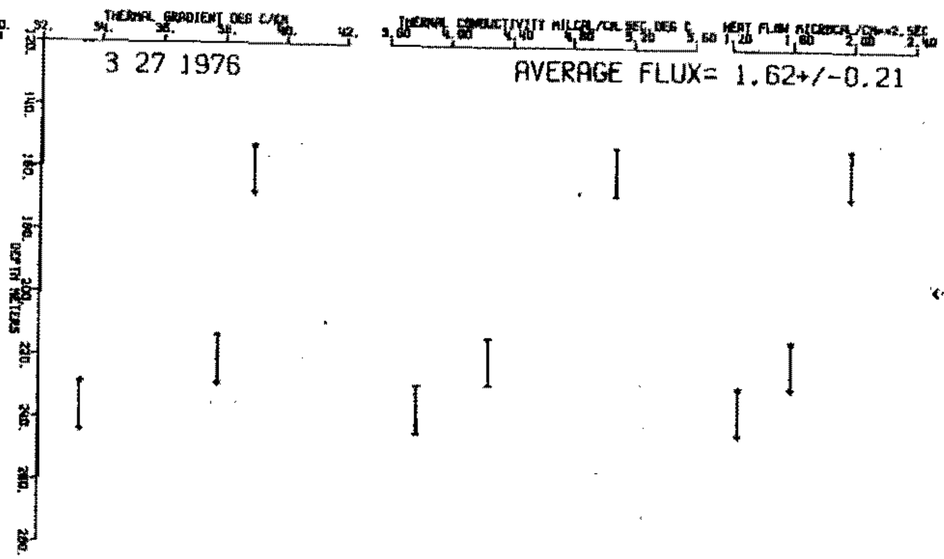
DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
152.40	167.64	5.10	39.01	1.99
213.36	228.60	4.26	37.85	1.61
228.60	243.84	3.80	33.40	1.27

AVERAGE HEAT FLUX= 1.62 +/- 0.21 H.F.U. STD DEV 0.359

METHOD #2 FLUX= 1.62 H.F.U. # OF CONDUCTIVITIES= 9.0
UPPER DEPTH 152.40 LOWER DEPTH 243.84 METERS


TEMPERATURE DEGREES C
NDSWC 4812 3 27 1976
DEPTH METERS


TEMPERATURE DEGREES C
NDSWC 4812
DEPTH METERS


THERMAL GRADIENT DEG C/KM
3 27 1976
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM SEC DEG C
HEAT FLOW MICROCAL/CM**2 SEC
AVERAGE FLUX= 1.62+/-0.21

NDSWC 4599 USGS OBSERVATION WATER WELL
DUNN COUNTY 144N 94W SECTION 7 DAA2
47 18' 49" NORTH LATITUDE 102 37' 52" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=19.48 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
8 13 1975	10 5 1973	10 1 1973	10 4 1973

DRILLING PERIOD= 3 DAYS DAYS SINCE 1ST PERIOD= 678
CASING SIZE 5.08CM ELEVATION 692.81 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	8450.00	0.0	29.05	
				-909.44
50.00	14700.00	15.24	15.19	
				-162.33
100.00	16300.00	30.48	12.72	
				-83.62
150.00	17200.00	45.72	11.44	
				-69.38
200.00	18000.00	60.96	10.39	
				-28.93
250.00	18350.00	76.20	9.95	
				29.78
300.00	17990.00	91.44	10.40	
				31.75
350.00	17615.00	106.68	10.88	
				26.74
400.00	17312.00	121.92	11.29	
				46.30
450.00	16803.00	137.16	12.00	
				32.72
502.00	16440.00	153.01	12.52	
				28.97
550.00	16150.00	167.64	12.94	
				28.21
650.00	15580.00	198.12	13.80	
				22.51
700.00	15359.00	213.36	14.14	
				44.42
750.00	14931.00	228.60	14.82	
				24.94
800.00	14696.00	243.84	15.20	
				57.62
851.00	14159.00	259.38	16.09	
				36.17
901.00	13840.00	274.62	16.65	
				30.80
950.00	13580.00	289.56	17.11	
				9.27
964.00	13558.00	293.83	17.15	

NDSWC 4599 USGS OBSERVATION WATER WELL

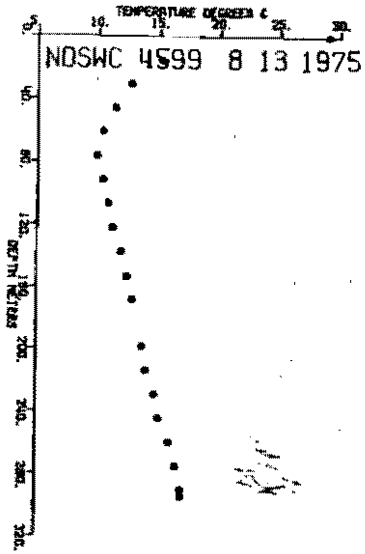
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
76.20	77.72	4.27	1.00	0.23
100.58	102.10	2.45	1.00	0.41
106.68	108.20	3.32	1.00	0.30
118.87	120.40	3.90	1.00	0.26
146.30	147.83	3.93	1.00	0.25
158.50	160.02	4.54	1.00	0.22
164.59	166.12	2.23	1.00	0.45
176.78	178.30	3.77	1.00	0.27
195.07	196.60	4.71	1.00	0.21
262.12	263.65	3.04	1.00	0.33
268.22	269.75	2.81	1.00	0.36

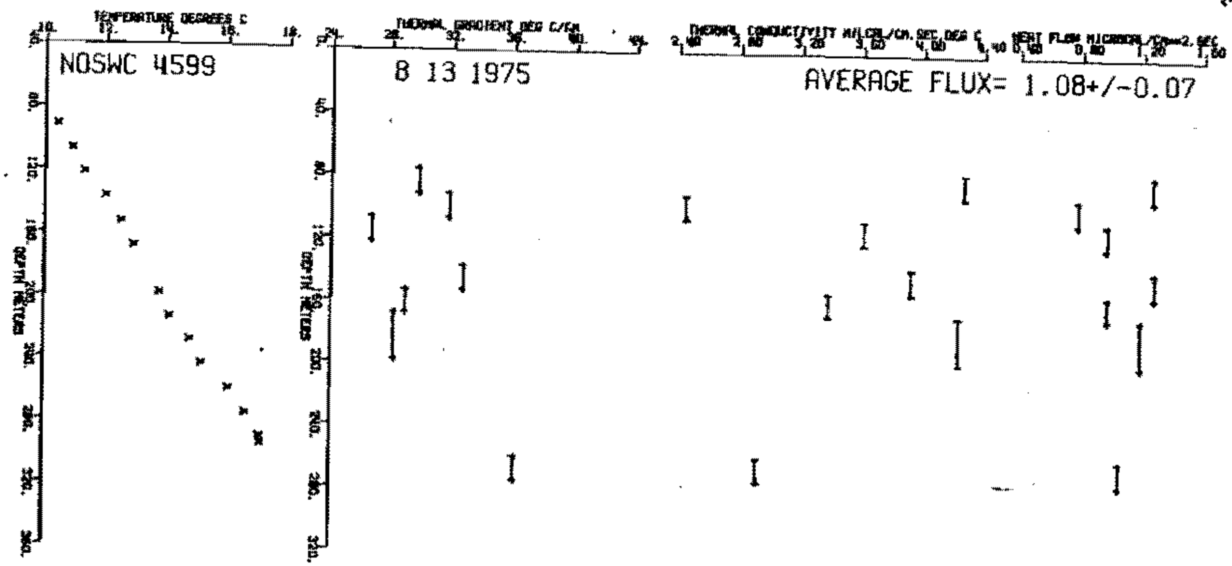
HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
76.20	91.44	4.27	29.78	1.27
91.44	106.68	2.45	31.75	0.78
106.68	121.92	3.61	26.74	0.97
137.16	153.01	3.93	32.72	1.29
153.01	167.64	3.38	28.97	0.98
167.64	198.12	4.24	28.21	1.20
259.38	274.62	2.92	36.17	1.06

AVERAGE HEAT FLUX= 1.08 +/- 0.07 H.F.U. STD DEV 0.186

METHOD #2 FLUX= 1.13 H.F.U. # OF CONDUCTIVITIES=11.0
UPPER DEPTH 76.20 LOWER DEPTH 274.62 METERS


TEMPERATURE DEGREES C
NOSWC 4599 8 13 1975
DEPTH METERS


TEMPERATURE DEGREES C
NOSWC 4599
DEPTH METERS
THERMAL GRADIENT DEG C/KM
8 13 1975
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.08+/-0.07

NDSWC 4814 USGS OBSERVATION WATER WELL
BILLINGS COUNTY 144N 100W SECTION 24 BDD
47 16' 40'' NORTH LATITUDE 103 17' 55'' WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG= 8.15 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
3 25 1976	8 30 1975	8 15 1975	8 18 1975

DRILLING PERIOD= 3 DAYS DAYS SINCE 1ST PERIOD= 219
CASING SIZE 10.16CM ELEVATION 777.24 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	19700.00	0.0	8.33	
				20.36
250.00	18400.00	76.20	9.88	
				37.23
300.00	17950.00	91.44	10.45	
				47.29
350.00	17400.00	106.68	11.17	
				60.43
400.00	16735.00	121.92	12.09	
				16.85
450.00	16555.00	137.16	12.35	
				54.29
500.00	15990.00	152.40	13.18	
				39.81
550.00	15590.00	167.64	13.78	
				40.98
600.00	15190.00	182.88	14.41	
				49.49
652.00	14700.00	198.73	15.19	
				39.58
700.00	14350.00	213.36	15.77	
				33.47
750.00	14050.00	228.60	16.28	
				40.08
800.00	13700.00	243.84	16.89	
				32.94
850.00	13420.00	259.08	17.39	
				20.41
900.00	13250.00	274.32	17.71	
				39.23
950.00	12930.00	289.56	18.30	
				85.29
1000.00	12265.00	304.80	19.60	
				28.18
1051.00	12050.00	320.34	20.04	
				37.16
1200.00	11260.00	365.76	21.73	
				20.57
1250.00	11120.00	381.00	22.04	
				31.45
1300.00	10910.00	396.24	22.52	
				35.24
1350.00	10680.00	411.48	23.06	
				35.37
1400.00	10455.00	426.72	23.60	
				37.87
1450.00	10220.00	441.96	24.17	
				76.17
1490.00	9855.00	454.15	25.10	

NDSWC 4814 USGS OBSERVATION WATER WELL

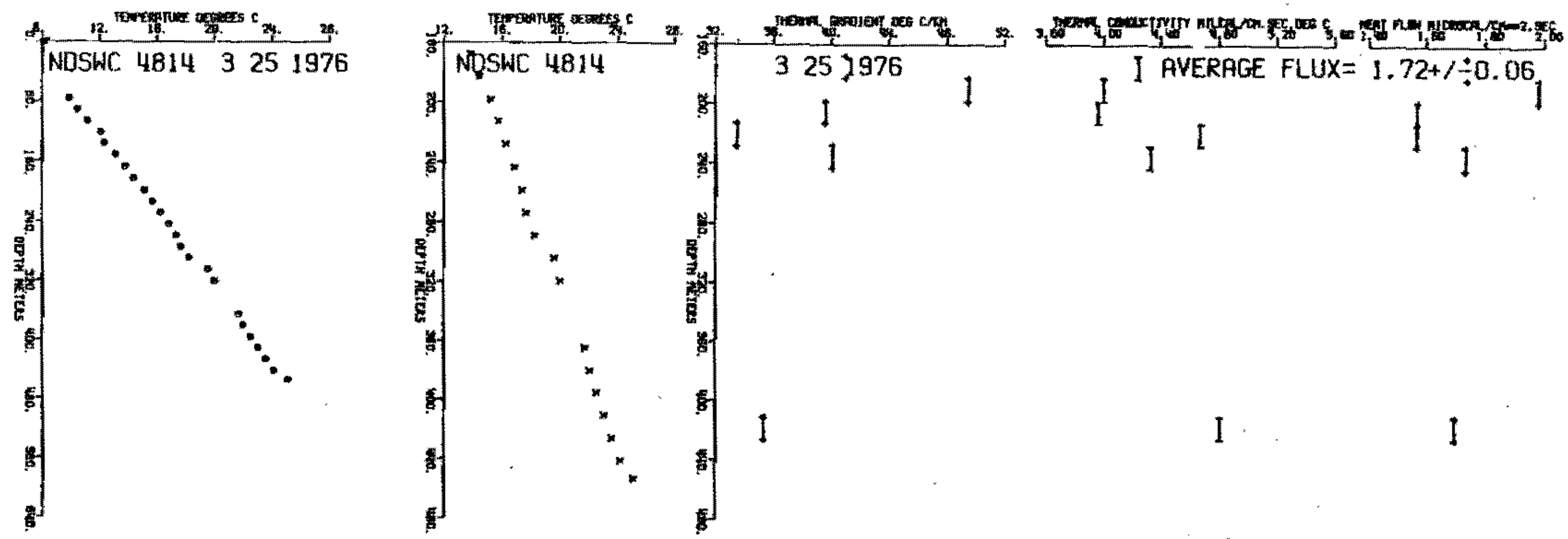
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
169.16	170.68	4.24	1.00	0.24
185.92	187.45	4.00	1.00	0.25
204.21	205.74	3.93	1.00	0.25
208.78	210.31	4.00	1.00	0.25
219.45	220.98	4.91	1.00	0.20
227.07	228.50	4.45	1.00	0.22
234.69	236.22	4.66	1.00	0.21
240.79	242.31	4.00	1.00	0.25
414.53	416.05	4.54	1.00	0.22
417.58	419.10	5.38	1.00	0.19
422.14	423.67	4.53	1.00	0.22

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
167.64	182.88	4.24	40.98	1.74
182.88	198.73	4.00	49.49	1.98
198.73	213.36	3.96	39.58	1.57
213.36	228.60	4.68	33.47	1.57
228.60	243.84	4.33	40.08	1.74
411.48	426.72	4.82	35.37	1.70

AVERAGE HEAT FLUX= 1.72 +/- 0.06 H.F.U. STD DEV 0.151

METHOD #2 FLUX= 1.73 H.F.U. # OF CONDUCTIVITIES=11.0
UPPER DEPTH 152.40 LOWER DEPTH 454.15 METERS


NDSWC 4814 3 25 1976
TEMPERATURE DEGREES C
DEPTH METERS
NDSWC 4814
TEMPERATURE DEGREES C
DEPTH METERS
3 25 1976
THERMAL GRADIENT DEG C/KM
DEPTH METERS
THERMAL CONDUCTIVITY MILLICAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.72+/-0.06

NDSWC 4815 USGS OBSERVATION WATER WELL
BILLINGS COUNTY 144N 100W SECTION 24 BDD
47 16' 40'' NORTH LATITUDE 103 17' 55'' WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=17.09 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
3 26 1976	8 30 1975	8 15 1975	8 18 1975

DRILLING PERIOD= 3 DAYS DAYS SINCE 1ST PERIOD= 220
CASING SIZE 5.08CM ELEVATION 777.24 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	25450.00	0.0	2.66	
				299.09
50.00	20700.00	15.24	7.22	
				70.90
100.00	19730.00	30.48	8.30	
				38.74
200.00	18730.00	60.96	9.48	
				34.79
250.00	18300.00	76.20	10.01	
				35.76
300.00	17870.00	91.44	10.55	
				34.38
350.00	17470.00	106.68	11.08	
				62.44
400.00	16780.00	121.92	12.03	
				55.71
451.00	16180.00	137.46	12.89	
				46.16
500.00	15720.00	152.40	13.58	
				37.53
550.00	15350.00	167.64	14.16	
				36.25
600.00	15000.00	182.88	14.71	
				46.81
650.00	14560.00	198.12	15.42	
				46.46
701.00	14130.00	213.66	16.14	
				35.91
750.00	13820.00	228.60	16.68	
				36.97
800.50	13500.00	243.99	17.25	
				37.54
850.00	13190.00	259.08	17.82	
				10.97
900.00	13100.00	274.32	17.98	
				39.78
950.00	12780.00	289.56	18.59	
				69.69
1002.00	12220.00	305.41	19.69	
				33.57
1050.00	11980.00	320.04	20.19	
				52.54
1100.00	11600.00	335.28	20.99	
				17.00
1150.00	11480.00	350.52	21.25	
				34.32
1200.50	11240.00	365.91	21.77	
				25.32
1250.00	11070.00	381.00	22.16	
				30.09
1300.00	10870.00	396.24	22.61	
				33.85
1350.00	10650.00	411.48	23.13	
				35.47
1400.00	10425.00	426.72	23.67	
				31.80

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
1450.00	10228.00	441.96	24.16	
				62.84
1490.00	9925.50	454.15	24.92	

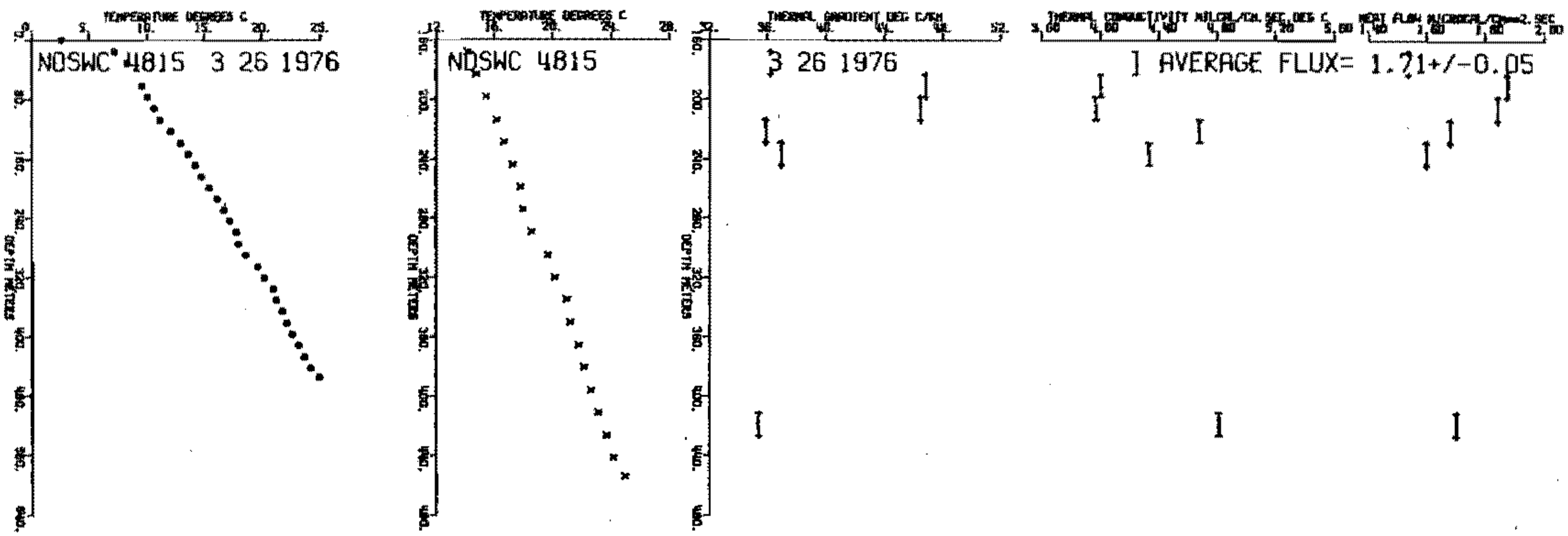
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
169.16	170.68	4.24	1.00	0.24
185.92	187.45	4.00	1.00	0.25
204.21	205.74	3.93	1.00	0.25
208.78	210.31	4.00	1.00	0.25
219.45	220.98	4.91	1.00	0.20
227.07	228.50	4.45	1.00	0.22
234.69	236.22	4.66	1.00	0.21
240.79	242.31	4.00	1.00	0.25
414.53	416.05	4.54	1.00	0.22
417.58	419.10	5.38	1.00	0.19
422.14	423.67	4.53	1.00	0.22

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
167.64	182.88	4.24	36.25	1.54
182.88	198.12	4.00	46.81	1.87
198.12	213.66	3.96	46.46	1.84
213.66	228.60	4.68	35.91	1.68
228.60	243.99	4.33	36.97	1.60
411.48	426.72	4.82	35.47	1.71

AVERAGE HEAT FLUX= 1.71 +/- 0.05 H.F.U. STD DEV 0.131

METHOD #2 FLUX= 1.65 H.F.U. # OF CONDUCTIVITIES=11.0
UPPER DEPTH 152.40 LOWER DEPTH 454.15 METERS



TEMPERATURE DEGREES C
NOSWC 4815 3 26 1976
DEPTH METERS
TEMPERATURE DEGREES C
NOSWC 4815
DEPTH METERS
THERMAL GRADIENT DEG C/KM
3 26 1976
DEPTH METERS
THERMAL CONDUCTIVITY
HEAT FLOW
] AVERAGE FLUX= 1.71+/-0.05

NDSWC 4814 USGS OBSERVATION WATER WELL
BILLINGS COUNTY 144N 100W SECTION 24 BDD
47 16' 40'' NORTH LATITUDE 103 17' 55'' WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=11.20 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
4 23 1976	8 30 1975	8 15 1975	8 18 1975

DRILLING PERIOD= 3 DAYS DAYS SINCE 1ST PERIOD= 248
CASING SIZE 10.16CM ELEVATION 777.24 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	20130.00	0.0	5.54	
				73.49
48.26	19200.00	14.71	6.62	
				74.74
96.80	18300.00	29.50	7.72	
				55.02
144.86	17675.00	44.15	8.53	
				40.02
193.02	17235.00	58.83	9.12	
				25.46
244.17	16945.00	74.42	9.51	
				55.52
289.53	16400.00	88.25	10.28	
				39.62
337.79	16000.00	102.96	10.86	
				33.12
386.14	15680.00	117.70	11.35	
				102.22
434.30	14745.00	132.37	12.85	
				45.15
482.84	14350.00	147.17	13.52	
				21.25
530.90	14170.00	161.82	13.83	
				52.40
579.25	13735.00	176.56	14.60	
				42.01
627.41	13395.00	191.23	15.22	
				43.48
675.57	13050.00	205.91	15.86	
				34.26
739.56	12700.00	225.42	16.53	
				32.44
772.18	12535.00	235.36	16.85	
				33.23
820.34	12290.00	250.04	17.34	
				31.87
868.59	12050.00	264.75	17.81	
				23.01
917.42	11895.00	279.63	18.15	
				71.43
965.20	11410.00	294.19	19.19	
				51.84
1013.36	11070.00	308.87	19.95	
				34.69
1061.80	10845.00	323.64	20.46	
				33.79
1110.35	10630.00	338.43	20.96	
				34.20
1158.31	10420.00	353.05	21.46	
				31.58
1206.38	10230.00	367.70	21.93	
				28.49
1255.02	10060.00	382.53	22.35	
				98.30
1312.54	9400.00	400.06	24.07	
				29.53

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
1352.11	9270.00	412.12	24.43	
				32.61
1399.88	9100.00	426.68	24.90	
				35.94
1448.13	8915.00	441.39	25.43	
				62.47
1496.97	8600.00	456.28	26.36	
				37.48
1546.19	8416.00	471.28	26.92	
				30.82
1595.41	8268.00	486.28	27.39	
				27.21
1640.77	8150.00	500.11	27.76	
				0.0
1650.32	8150.00	503.02	27.76	

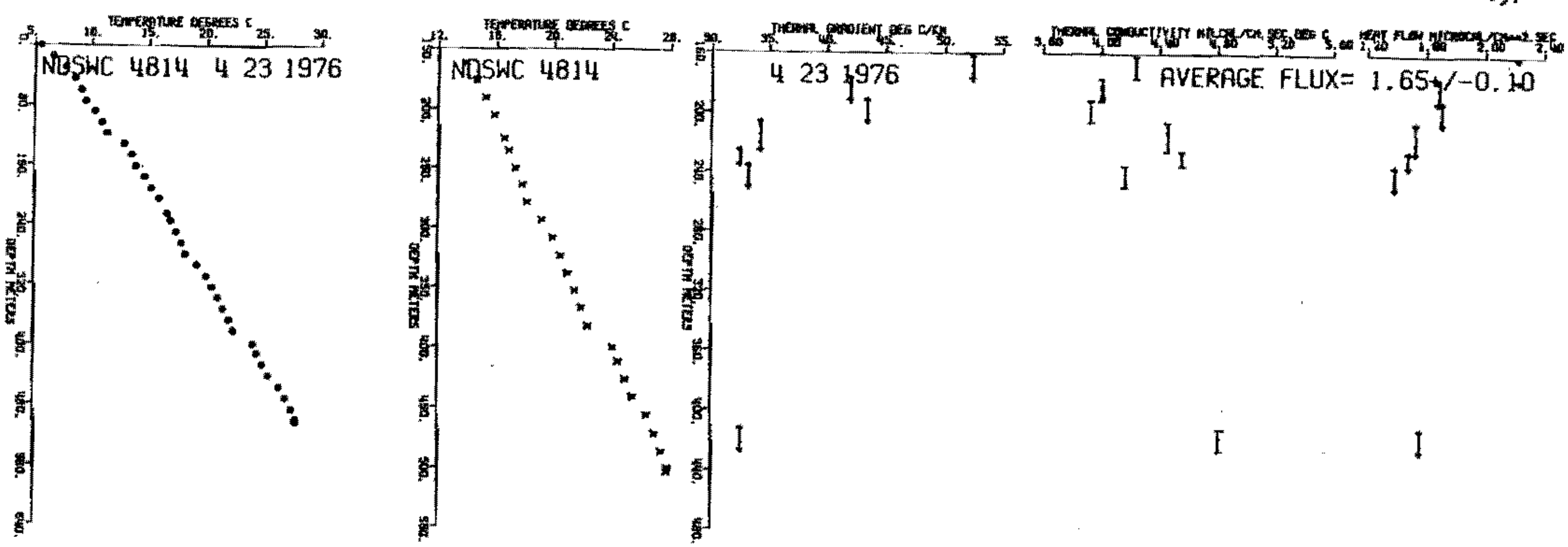
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
169.16	170.68	4.24	1.00	0.24
185.92	187.45	4.00	1.00	0.25
204.21	205.74	3.93	1.00	0.25
208.78	210.31	4.00	1.00	0.25
219.45	220.98	4.91	1.00	0.20
227.07	228.60	4.45	1.00	0.22
234.69	235.22	4.66	1.00	0.21
235.40	236.22	4.33	1.00	0.23
240.79	242.31	4.00	1.00	0.25
414.53	416.05	4.54	1.00	0.22
417.58	419.10	5.38	1.00	0.19
422.14	423.67	4.53	1.00	0.22

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
161.82	176.56	4.24	52.40	2.22
176.56	191.23	4.00	42.01	1.68
191.23	205.91	3.93	43.48	1.71
205.91	225.42	4.45	34.26	1.53
225.42	235.36	4.55	32.44	1.48
235.36	250.04	4.16	33.23	1.38
412.12	426.68	4.82	32.61	1.57

AVERAGE HEAT FLUX= 1.65 +/- 0.10 H.F.U. STD DEV 0.275

METHOD #2 FLUX= 1.82 H.F.U. # OF CONDUCTIVITIES=12.0
UPPER DEPTH 147.17 LOWER DEPTH 456.28 METERS



TEMPERATURE DEGREES C
NDSWC 4814 4 23 1976
DEPTH METERS
TEMPERATURE DEGREES C
NDSWC 4814
DEPTH METERS
THERMAL GRADIENT DEG C/KM
4 23 1976
DEPTH METERS
AVERAGE FLUX= 1.65+/-0.10

NDSWC 4815 USGS OBSERVATION WATER WELL
BILLINGS COUNTY 144N 100W SECTION 24 BDD
47 16' 40'' NORTH LATITUDE 103 17' 55'' WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=20.00 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
4 23 1976	8 30 1975	8 15 1975	8 18 1975

DRILLING PERIOD= 3 DAYS DAYS SINCE 1ST PERIOD= 248
CASING SIZE 5.08CM ELEVATION 777.24 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	20750.00	0.0	4.85	
				135.60
48.35	19010.00	14.74	6.85	
				162.58
96.51	17150.00	29.42	9.23	
				27.07
144.86	16860.00	44.15	9.63	
				53.11
193.02	16310.00	58.83	10.41	
				61.63
241.47	15700.00	73.60	11.32	
				77.96
295.13	14900.00	89.96	12.60	
				51.51
347.44	14410.00	105.90	13.42	
				21.23
443.95	14050.00	135.32	14.04	
				-25.09
482.83	14220.00	147.17	13.75	
				26.32
530.89	14000.00	161.82	14.13	
				41.54
579.06	13660.00	176.50	14.74	
				43.49
675.57	12965.00	205.91	16.02	
				37.16
723.83	12680.00	220.62	16.57	
				33.03
788.49	12350.00	240.33	17.22	
				30.27
821.30	12200.00	250.33	17.52	
				32.08
868.59	11975.00	264.75	17.98	
				24.20
916.85	11805.00	279.46	18.34	
				58.62
965.10	11405.00	294.16	19.20	
				60.01
1013.55	11010.00	308.93	20.09	
				31.97
1061.61	10805.00	323.58	20.56	
				34.11
1109.89	10590.00	338.29	21.06	
				35.80
1158.15	10370.00	353.00	21.58	
				30.78
1206.42	10185.00	367.72	22.04	
				115.45
1254.66	9525.00	382.42	23.73	
				30.36
1302.89	9360.00	397.12	24.18	
				29.91
1351.30	9200.00	411.88	24.62	
				30.35
1399.97	9040.00	426.71	25.07	
				33.52

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
1447.71	8870.50	441.26	25.56	
				52.38
1496.00	8610.00	455.98	26.33	
				45.10
1545.16	8389.00	470.96	27.01	
				4.32
1547.57	8388.00	471.70	27.01	

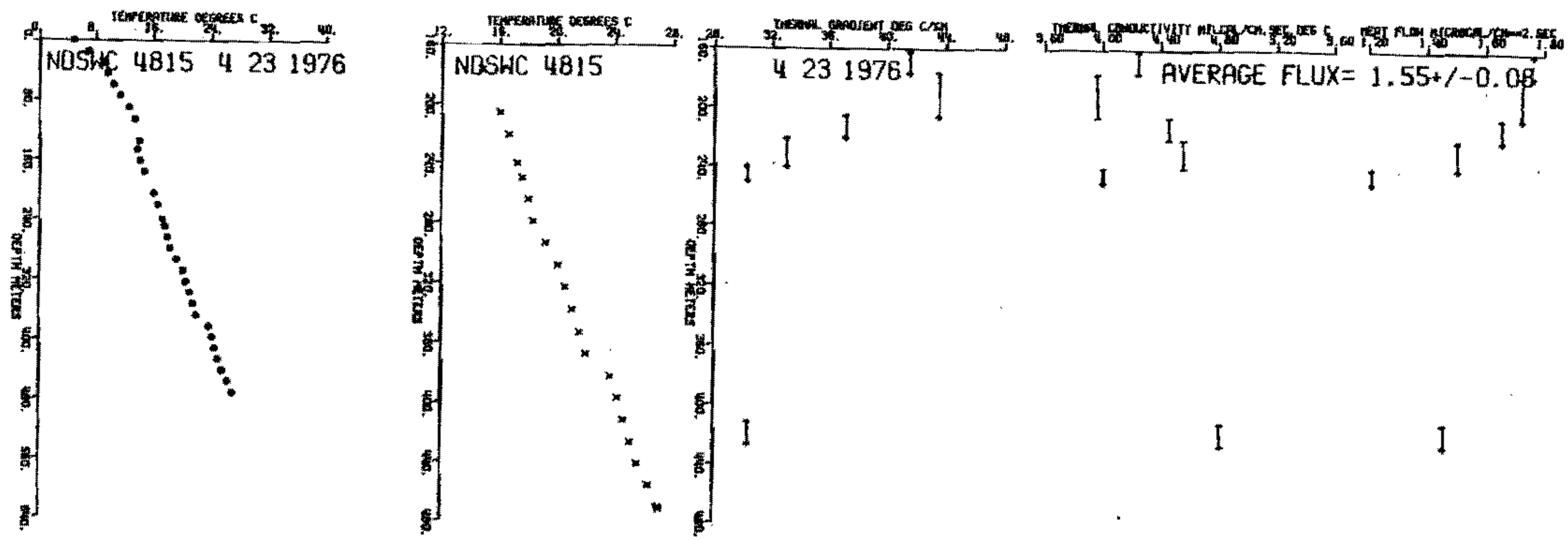
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
169.16	170.68	4.24	1.00	0.24
185.92	187.45	4.00	1.00	0.25
204.21	205.74	3.93	1.00	0.25
208.78	210.31	4.00	1.00	0.25
219.45	220.50	4.91	1.00	0.20
227.07	228.60	4.45	1.00	0.22
234.69	236.22	4.66	1.00	0.21
240.79	242.31	4.00	1.00	0.25
414.53	416.05	4.54	1.00	0.22
417.58	419.10	5.38	1.00	0.19
422.14	423.67	4.53	1.00	0.22

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
161.82	176.50	4.24	41.54	1.76
176.50	205.91	3.96	43.49	1.72
205.91	220.62	4.45	37.16	1.66
220.62	240.33	4.55	33.03	1.50
240.33	250.33	4.00	30.27	1.21
411.88	426.71	4.82	30.35	1.46

AVERAGE HEAT FLUX= 1.55 +/- 0.08 H.F.U. STD DEV 0.205

METHOD #2 FLUX= 1.82 H.F.U. # OF CONDUCTIVITIES=11.0
UPPER DEPTH 161.82 LOWER DEPTH 455.98 METERS


TEMPERATURE DEGREES C
NDSWC 4815 4 23 1976
DEPTH METERS
TEMPERATURE DEGREES C
NDSWC 4815
DEPTH METERS
THERMAL GRADIENT DEG C/KM
4 23 1976
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.55+/-0.08

NDSWC 3991 USGS OBSERVATION WATER WELL
STEELE COUNTY 145N 54W SECTION 27 CDC
47 20' 24" NORTH LATITUDE 97 31' 52" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=19.00 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
2 22 1975	6 2 1970	6 1 1970	6 2 1970

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 1725
CASING SIZE 10.16CM ELEVATION 249.94 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
100.00	24900.00	30.48	3.13	
				11.53
150.00	24700.00	45.72	3.31	
				14.42
160.00	24650.00	48.77	3.35	
				24.83
180.00	24480.00	54.86	3.50	
				26.47
200.00	24300.00	60.96	3.67	
				19.22
220.00	24170.00	67.06	3.78	
				25.35
240.00	24000.00	73.15	3.94	
				40.69
260.00	23730.00	79.25	4.19	
				38.13
280.00	23480.00	85.34	4.42	
				52.66
300.00	23140.00	91.44	4.74	
				79.14
320.00	22540.00	97.54	5.22	
				90.99
340.00	22080.00	103.63	5.78	
				75.13
360.00	21630.00	109.73	6.23	
				96.04
380.00	21070.00	115.82	6.82	
				88.27
400.00	20570.00	121.92	7.36	
				84.34
420.00	20105.00	128.02	7.87	
				34.76
425.00	20058.00	129.54	7.93	

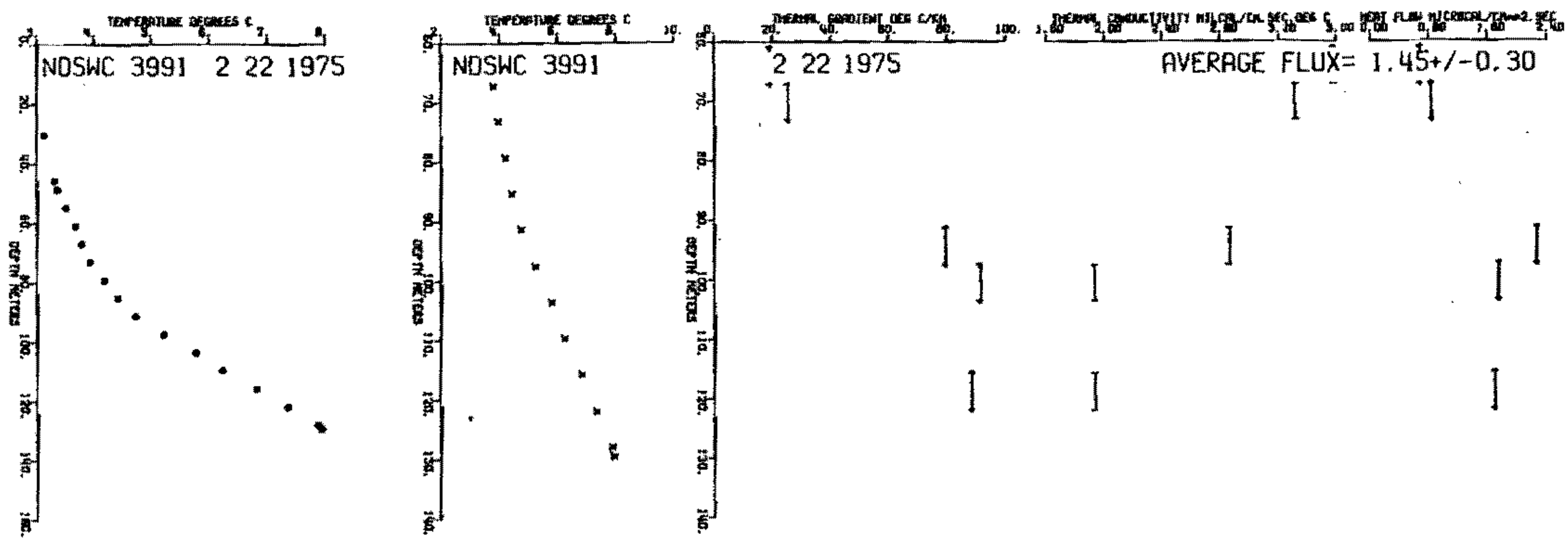
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
60.96	62.48	3.58	1.00	0.28
71.63	73.15	3.32	1.00	0.30
96.01	97.54	2.86	1.00	0.35
102.11	103.63	1.93	1.00	0.52
120.70	121.90	1.93	1.00	0.52

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
60.96	67.06	3.58	19.22	0.69
67.06	73.15	3.32	25.35	0.84
91.44	97.54	2.86	79.14	2.26
97.54	103.63	1.93	90.99	1.76
115.82	121.92	1.93	88.27	1.70

AVERAGE HEAT FLUX= 1.45 +/- 0.30 H.F.U. STD DEV 0.665

METHOD #2 FLUX= 1.54 H.F.U. # OF CONDUCTIVITIES= 5.0
UPPER DEPTH 60.96 LOWER DEPTH 121.92 METERS


NDSWC 3991 2 22 1975
TEMPERATURE DEGREES C
DEPTH METERS
NDSWC 3991
TEMPERATURE DEGREES C
DEPTH METERS
2 22 1975
THERMAL GRADIENT DEG C/KM
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM SEC DEG C
HEAT FLOW MICROCAL/CM**2 SEC
AVERAGE FLUX= 1.45+/-0.30

NDSWC 3991 USGS OBSERVATION WATER WELL
STEELE COUNTY 145N 54W SECTION 27 CDC
47 20' 24" NORTH LATITUDE 97 31' 52" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=16.35 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
3 14 1975	6 2 1970	6 1 1970	6 2 1970

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 1745
CASING SIZE 10.16CM ELEVATION 249.94 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	36200.00	0.0	-4.59	
				449.13
50.00	25930.00	15.24	2.25	
				22.11
100.00	25530.00	30.48	2.59	
				26.46
150.00	25060.00	45.72	2.99	
				34.40
170.00	24820.00	51.82	3.20	
				18.78
190.00	24690.00	57.91	3.32	
				16.70
210.00	24575.00	64.01	3.42	
				28.56
230.00	24380.00	70.10	3.59	
				17.70
250.00	24260.00	76.20	3.70	
				-17.70
260.00	24320.00	79.25	3.65	
				20.67
270.00	24250.00	82.30	3.71	
				80.34
280.00	23980.00	85.34	3.96	
				57.27
290.00	23790.00	88.39	4.13	
				63.92
300.00	23580.00	91.44	4.33	
				58.31
310.00	23390.00	94.49	4.50	
				58.95
320.00	23200.00	97.54	4.68	
				68.80
330.00	22980.00	100.58	4.89	
				88.75
340.00	22700.00	103.63	5.16	
				69.13
350.00	22485.00	106.68	5.37	
				76.41
360.00	22250.00	109.73	5.61	
				65.68
370.00	22050.00	112.78	5.81	
				89.87
380.00	21780.00	115.82	6.08	
				94.52
390.00	21500.00	118.87	6.37	
				109.90
400.00	21180.00	121.92	6.70	
				97.64
410.00	20900.00	124.97	7.00	
				84.90
420.00	20660.00	128.02	7.26	
				39.33
430.00	20550.00	131.06	7.38	

NDSWC 3991 USGS OBSERVATION WATER WELL

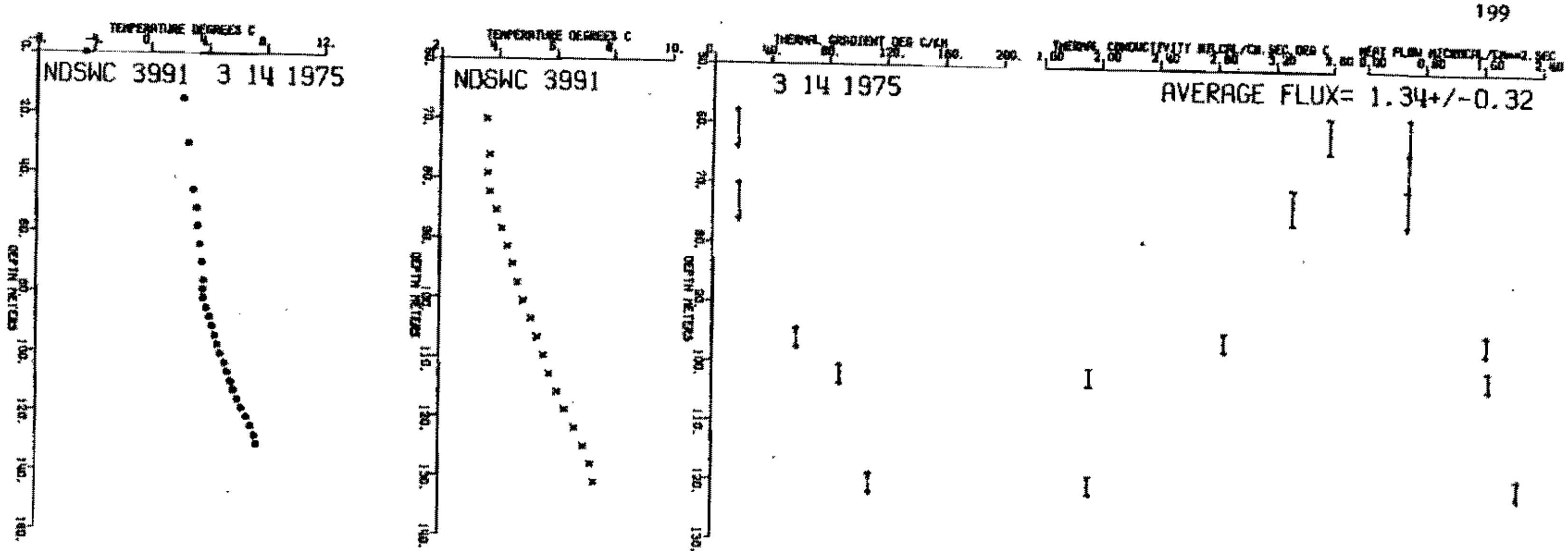
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
60.96	62.48	3.58	1.00	0.28
71.63	73.15	3.32	1.00	0.30
96.01	97.54	2.86	1.00	0.35
102.11	103.63	1.93	1.00	0.52
120.70	121.90	1.93	1.00	0.52

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
57.91	64.01	3.58	16.70	0.60
70.10	76.20	3.32	17.70	0.59
94.49	97.54	2.86	58.95	1.69
100.58	103.63	1.93	88.75	1.71
118.87	121.92	1.93	109.90	2.12

AVERAGE HEAT FLUX= 1.34 +/- 0.32 H.F.U. STD DEV 0.705

METHOD #2 FLUX= 1.34 H.F.U. # OF CONDUCTIVITIES= 5.0
UPPER DEPTH 57.91 LOWER DEPTH 121.92 METERS


NDSWC 3991 3 14 1975
NDSWC 3991
3 14 1975
AVERAGE FLUX= 1.34+/-0.32
TEMPERATURE DEGREES C
THERMAL GRADIENT DEG C/KM
DEPTH METERS

NDSWC 3991 USGS OBSERVATION WATER WELL
STEELE COUNTY 145N 54W SECTION 27 CDC
47 20' 24" NORTH LATITUDE 97 31' 52" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=22.00 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
7 27 1975	6 2 1970	6 1 1970	6 2 1970

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 1880
CASING SIZE 10.16CM ELEVATION 249.94 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	9100.00	0.0	27.14	
				-762.43
50.00	14500.00	15.24	15.52	
				-550.60
100.00	20780.00	30.48	7.13	
				16.39
150.00	20550.00	45.72	7.38	
				19.50
200.00	20280.00	60.96	7.68	
				28.82
255.00	19850.00	77.72	8.16	
				50.64
300.00	19250.00	91.44	8.85	
				73.75
325.00	18780.00	99.06	9.42	
				4.81
350.00	18750.00	106.68	9.45	
				82.63
375.00	18240.00	114.30	10.08	
				31.53
400.00	18050.00	121.92	10.32	
				4.13
425.00	18025.00	129.54	10.35	
				25.31
430.00	17995.00	131.06	10.39	

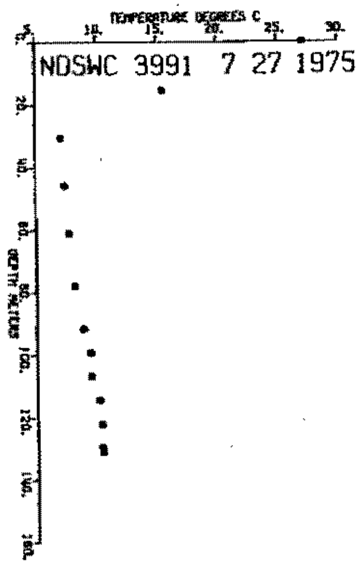
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
60.96	62.48	3.58	1.00	0.28
71.63	73.15	3.32	1.00	0.30
96.01	97.54	2.86	1.00	0.35
102.11	103.63	1.93	1.00	0.52
120.70	121.90	1.93	1.00	0.52

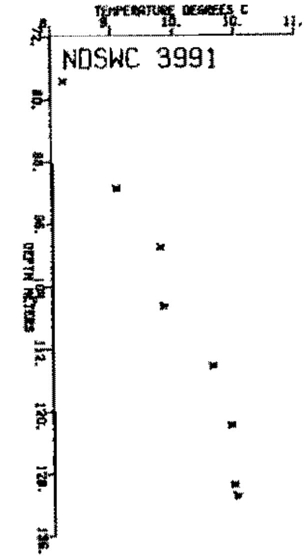
HEAT FLUX CALCULATION INTERVAL METHOD

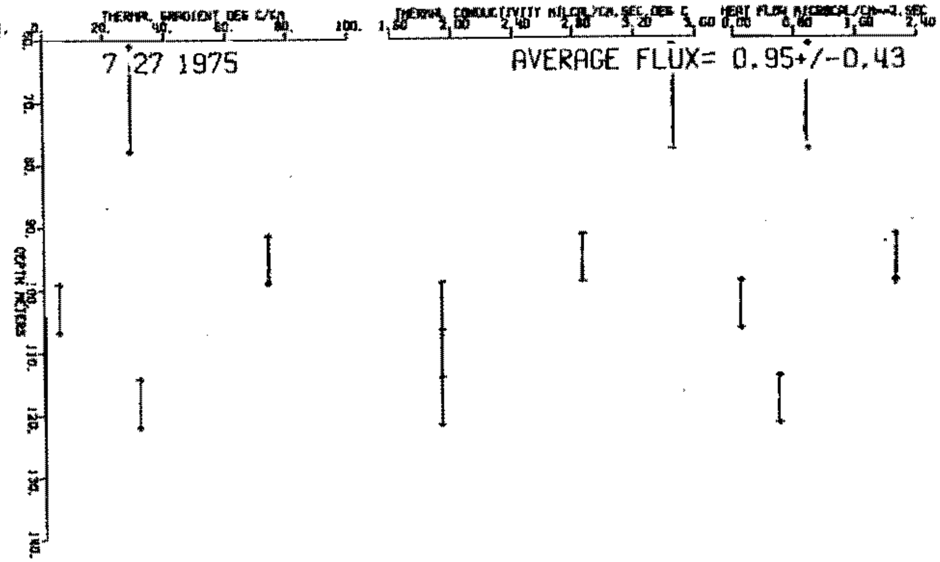
DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
60.96	77.72	3.45	28.82	0.99
91.44	99.06	2.86	73.75	2.11
99.06	106.68	1.93	4.81	0.09
114.30	121.92	1.93	31.53	0.61

AVERAGE HEAT FLUX= 0.95 +/- 0.43 H.F.U. STD DEV 0.856

METHOD #2 FLUX= 1.10 H.F.U. # OF CONDUCTIVITIES= 5.0
UPPER DEPTH 60.96 LOWER DEPTH 121.92 METERS


TEMPERATURE DEGREES C
NDSWC 3991 7 27 1975
DEPTH METERS


TEMPERATURE DEGREES C
NDSWC 3991
DEPTH METERS


THERMAL GRADIENT DEG C/KM
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
7 27 1975
AVERAGE FLUX= 0.95+/-0.43
DEPTH METERS

NDSWC 3575 USGS OBSERVATION WATER WELL
MERCER COUNTY 146N 90W SECTION 20 CCC
47 26' 41" NORTH LATITUDE 102 10' 59" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=24.00 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
5 14 1975	6 15 1968	6 14 1968	6 15 1968

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 2523
CASING SIZE 10.16CM ELEVATION 646.18 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
50.00	19000.00	15.24	9.15	
				-65.15
100.00	19851.00	30.48	8.16	
				16.76
150.00	19628.00	45.72	8.41	
				18.89
200.00	19380.00	60.96	8.70	
				20.97
250.00	19109.00	76.20	9.02	
				20.52
300.00	18848.00	91.44	9.33	
				31.38
350.00	18457.00	106.68	9.81	
				32.65
400.00	18060.00	121.92	10.31	
				31.70
450.00	17684.00	137.16	10.79	
				34.70
500.00	17289.00	152.40	11.32	
				27.95
550.00	16980.00	167.64	11.75	
				27.15
600.00	16586.00	182.88	12.16	
				27.91
650.00	16390.00	198.12	12.59	
				26.35
700.00	16116.00	213.36	12.99	
				33.74
750.00	15773.00	228.60	13.50	
				0.83
775.00	15769.00	236.22	13.51	

NOSWC 3575 USGS OBSERVATION WATER WELL

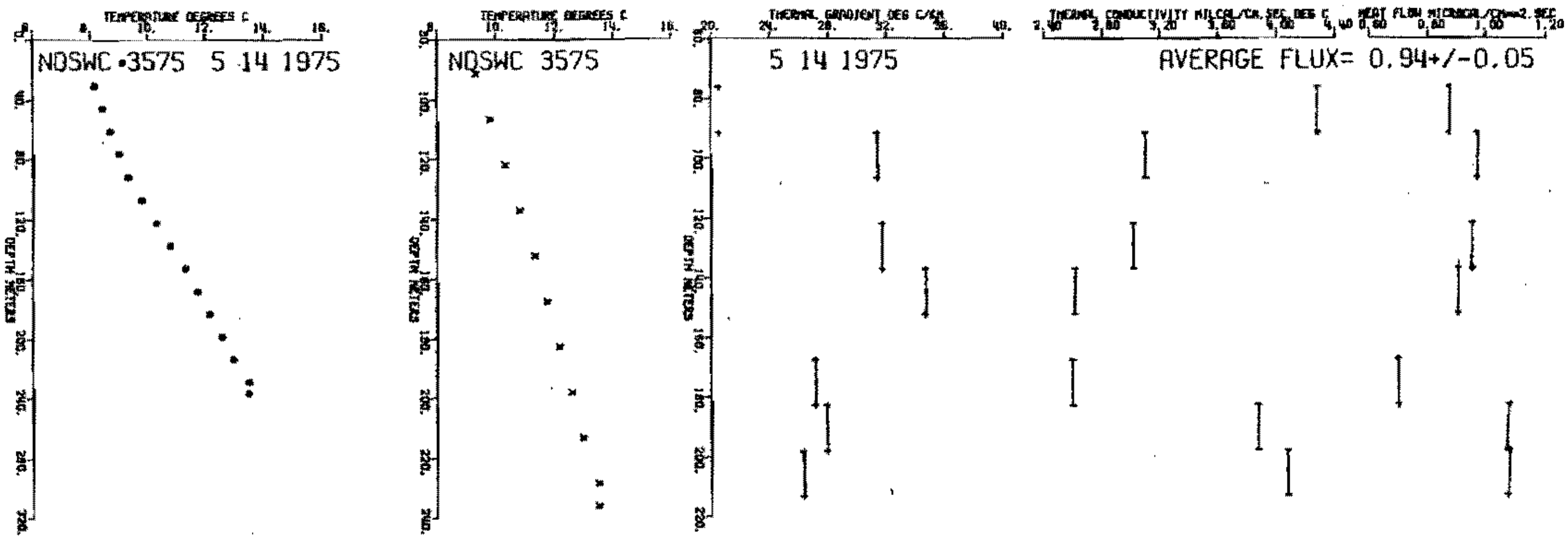
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
82.30	83.82	4.28	1.00	0.23
103.63	105.15	3.10	1.00	0.32
124.97	134.49	3.01	1.00	0.33
146.30	147.83	2.61	1.00	0.38
167.64	169.16	2.59	1.00	0.39
188.98	190.50	3.87	1.00	0.26
199.64	201.17	4.07	1.00	0.25

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
76.20	91.44	4.28	20.52	0.88
91.44	106.68	3.10	31.38	0.97
121.92	137.16	3.01	31.70	0.95
137.16	152.40	2.61	34.70	0.91
167.64	182.88	2.59	27.15	0.70
182.88	198.12	3.87	27.91	1.08
198.12	213.36	4.07	26.35	1.07

AVERAGE HEAT FLUX= 0.94 +/- 0.05 H.F.U. STD DEV 0.129

METHOD #2 FLUX= 0.94 H.F.U. # OF CONDUCTIVITIES= 7.0
UPPER DEPTH 76.20 LOWER DEPTH 213.36 METERS


NDSWC 3575 5 14 1975
TEMPERATURE DEGREES C
DEPTH METERS
NDSWC 3575
TEMPERATURE DEGREES C
DEPTH METERS
5 14 1975
THERMAL GRADIENT DEG C/KM
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 0.94+/-0.05

NDSWC 3575 USGS OBSERVATION WATER WELL
MERCER COUNTY 146N 90W SECTION 20 CCC
47 26' 41" NORTH LATITUDE 102 10' 59" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=23.25 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
4 22 1975	6 15 1968	6 14 1968	6 15 1968

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 2501
CASING SIZE 10.16CM ELEVATION 646.18 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	16220.00	0.0	10.54	
				-31.13
50.00	16550.00	15.24	10.07	
				-71.98
100.40	17350.00	30.60	8.96	
				8.93
150.00	17250.00	45.72	9.10	
				26.02
200.00	16960.00	60.96	9.49	
				34.41
250.00	16585.00	76.20	10.02	
				-47.76
301.10	17120.00	91.78	9.27	
				96.63
350.10	16100.00	106.71	10.72	
				14.58
400.00	15950.00	121.92	10.94	
				42.20
460.10	15450.00	140.24	11.71	
				-38.42
500.00	15750.00	152.40	11.24	
				46.26
550.00	15300.00	167.64	11.95	
				21.07
600.00	15100.00	182.88	12.27	
				26.80
650.00	14850.00	198.12	12.68	
				3.27
700.00	14820.00	213.36	12.73	
				48.51
750.10	14380.00	228.63	13.47	

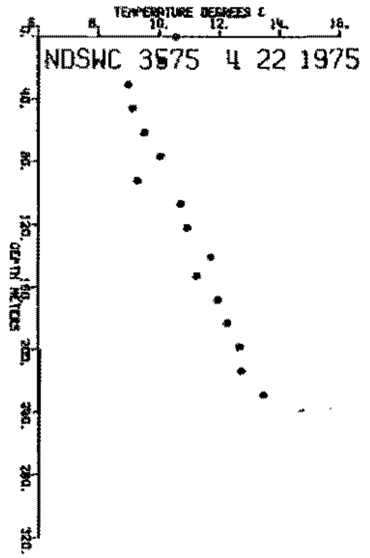
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
124.97	134.49	3.01	1.00	0.33
167.64	169.16	2.59	1.00	0.39
188.98	190.50	4.87	1.00	0.21
199.64	201.17	4.07	1.00	0.25

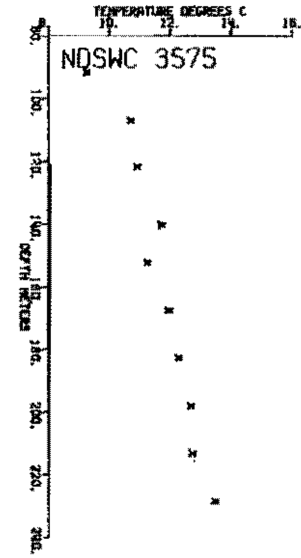
HEAT FLUX CALCULATION INTERVAL METHOD

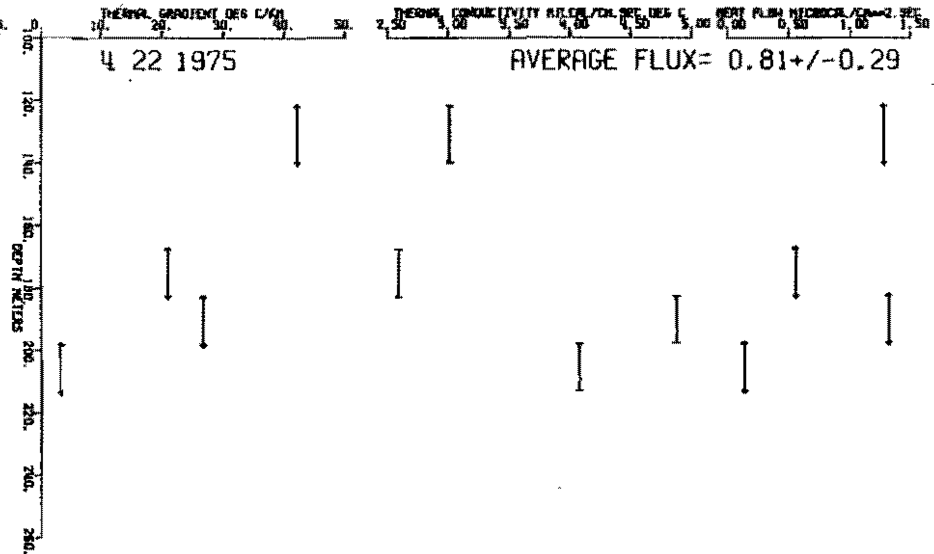
DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
121.92	140.24	3.01	42.20	1.27
167.64	182.88	2.59	21.07	0.55
182.88	198.12	4.87	26.80	1.31
198.12	213.36	4.07	3.27	0.13

AVERAGE HEAT FLUX= 0.81 +/- 0.29 H.F.U. STD DEV 0.573

METHOD #2 FLUX= 0.68 H.F.U. # OF CONDUCTIVITIES= 4.0
UPPER DEPTH 76.20 LOWER DEPTH 213.36 METERS


TEMPERATURE DEGREES C
NDSWC 3575 4 22 1975
DEPTH METERS


TEMPERATURE DEGREES C
NDSWC 3575
DEPTH METERS


THERMAL GRADIENT DEG C/KM
4 22 1975
DEPTH METERS
AVERAGE FLUX= 0.81+/-0.29

NDSWC 4597 USGS OBSERVATION WATER WELL
DUNN COUNTY 146N 96W SECTION 14 CDD
47 27' 35" NORTH LATITUDE 102 52' 37" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=18.22 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
8 14 1975	7 30 1973	7 14 1973	7 16 1973

DRILLING PERIOD= 2 DAYS DAYS SINCE 1ST PERIOD= 759
CASING SIZE 5.08CM ELEVATION 771.45 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	12745.00	0.0	18.66	
				-353.49
51.00	16000.00	15.54	13.16	
				-231.32
101.00	18600.00	30.78	9.64	
				-36.42
150.00	19050.00	45.72	9.09	
				5.86
200.00	18975.00	60.96	9.18	
				32.15
259.00	18500.00	78.94	9.76	
				29.72
310.00	18130.00	94.49	10.22	
				40.01
399.00	17300.00	121.62	11.31	
				52.37
454.00	16670.00	138.38	12.19	
				31.24
510.00	16300.00	155.45	12.72	
				49.26
548.00	15915.00	167.03	13.29	
				53.73
560.00	15785.00	170.69	13.49	

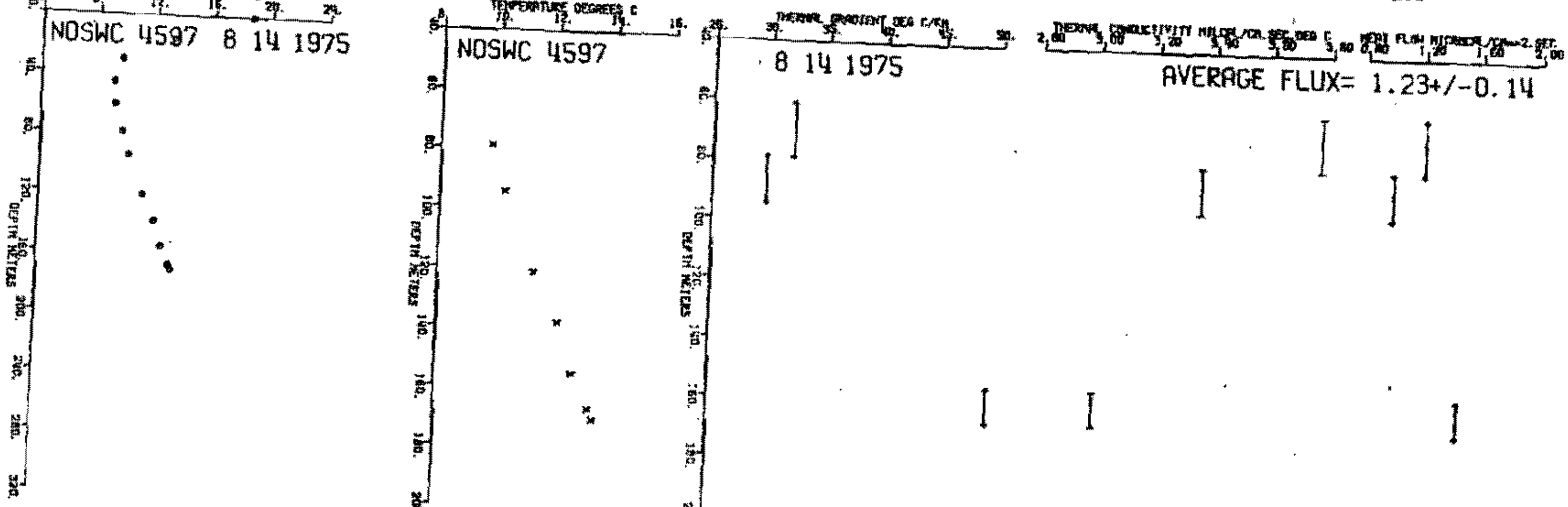
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
62.48	64.01	3.97	1.00	0.25
65.53	67.06	3.72	1.00	0.27
68.58	70.10	4.41	1.00	0.23
71.63	73.15	3.14	1.00	0.32
74.68	76.20	3.61	1.00	0.28
80.77	82.30	3.27	1.00	0.31
83.82	85.34	3.50	1.00	0.29
89.92	91.44	3.30	1.00	0.30
156.97	158.50	3.32	1.00	0.30
160.02	161.57	2.24	1.00	0.45
163.07	164.59	3.43	1.00	0.29

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
60.96	78.94	3.77	32.15	1.21
78.94	94.49	3.36	29.72	1.00
155.45	167.03	3.00	49.26	1.48

AVERAGE HEAT FLUX= 1.23 +/- 0.14 H.F.U. STD DEV 0.240

METHOD #2 FLUX= 1.30 H.F.U. # OF CONDUCTIVITIES=11.0
UPPER DEPTH 60.96 LOWER DEPTH 167.03 METERS



NOSWC 4597 8 14 1975
TEMPERATURE DEGREES C
DEPTH METERS
NOSWC 4597
TEMPERATURE DEGREES C
DEPTH METERS
8 14 1975
THERMAL GRADIENT DEG C/KM.
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC.
AVERAGE FLUX= 1.23+/-0.14

NDGS 5086 BARNWELL STATE 1-16
MCKENZIE COUNTY 146N 103W SECTION 16 NE NE
47 28' 25" NORTH LATITUDE 103 47' 58" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=15.00 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
7 24 1976	7 3 1972	5 27 1972	6 29 1972

DRILLING PERIOD= 33 DAYS DAYS SINCE 1ST PERIOD= 1485
CASING SIZE 11.86CM ELEVATION 722.07 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	5300.00	0.0	39.33	
				-1007.15
100.00	17600.00	30.48	8.63	
				23.41
200.00	17070.00	60.96	9.34	
				38.22
303.00	16220.00	92.35	10.54	
				48.41
400.00	15285.00	121.92	11.97	
				52.46
500.00	14320.00	152.40	13.57	
				38.45
600.00	13658.00	182.88	14.74	
				35.42
700.00	13069.00	213.36	15.82	
				36.05
800.20	12497.00	243.90	16.93	
				45.02
900.00	11826.00	274.32	18.29	
				40.27
1000.00	11260.00	304.80	19.52	
				40.77
1111.20	10655.00	338.69	20.90	
				47.66
1141.40	10470.00	347.90	21.34	
				43.36
1201.40	10145.00	366.19	22.14	
				51.25
1231.30	9959.00	375.30	22.60	
				36.65
1400.00	9248.30	426.72	24.49	
				25.88
1521.50	8909.80	463.75	25.45	
				27.69
1551.50	8822.80	472.90	25.70	
				22.77
1582.10	8750.50	482.22	25.91	
				27.19
1511.80	8667.80	491.28	26.16	
				44.97
1731.70	8137.80	527.82	27.80	
				39.65
1761.70	8026.00	536.97	28.16	
				39.54
1791.80	7916.00	546.14	28.53	
				40.01
1900.10	7525.00	579.15	29.85	
				44.86
1941.90	7362.80	591.89	30.42	
				37.31
1972.00	7267.70	601.07	30.76	
				47.26
2100.20	6778.50	640.14	32.61	
				43.15
2212.40	6415.00	674.34	34.08	
				47.47

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
2242.20	6313.20	683.42	34.51	
				45.55
2300.20	6128.00	701.10	35.32	
				46.66
2392.60	5840.20	729.26	36.63	
				42.35
2412.40	5786.20	735.30	36.89	
				50.45
2533.20	5410.80	772.12	38.75	
				49.48
2562.50	5326.00	781.05	39.19	
				51.71
2593.20	5235.00	790.41	39.67	
				49.59
2622.60	5153.00	799.37	40.12	
				50.80
2700.40	4938.30	823.08	41.32	
				51.06
2800.30	4676.50	853.53	42.88	
				42.80
2901.30	4467.50	884.32	44.19	
				41.85
3000.20	4276.50	914.46	45.46	
				47.54
3113.40	4042.00	948.96	47.10	
				64.27
3143.10	3962.50	958.02	47.68	
				48.93
3300.20	3660.00	1005.90	50.02	
				40.50
3401.10	3510.00	1036.66	51.27	
				39.69
3500.20	3372.50	1066.86	52.47	
				47.84
3654.50	3129.50	1113.89	54.71	
				44.07
3683.60	3088.90	1122.76	55.11	
				40.85
3800.20	2943.40	1158.30	56.56	
				38.76
3893.90	2837.90	1186.86	57.66	
				37.10
3914.00	2816.80	1192.99	57.89	
				43.32
4000.00	2715.00	1219.20	59.03	
				46.22
4100.50	2595.00	1249.83	60.44	
				48.92
4200.80	2475.00	1280.40	61.94	
				50.66
4304.30	2354.00	1311.95	63.54	
				30.51
4334.60	2333.40	1321.19	63.82	
				44.48
4394.30	2275.40	1339.38	64.63	
				55.82
4424.50	2239.50	1348.59	65.14	
				58.65
4500.20	2148.00	1371.66	66.50	
				50.16
4664.70	1989.50	1421.80	69.01	
				53.37
4694.60	1960.50	1430.91	69.50	
				53.61
4754.80	1902.60	1449.26	70.48	

NDGS 5086 BARNWELL STATE 1-16

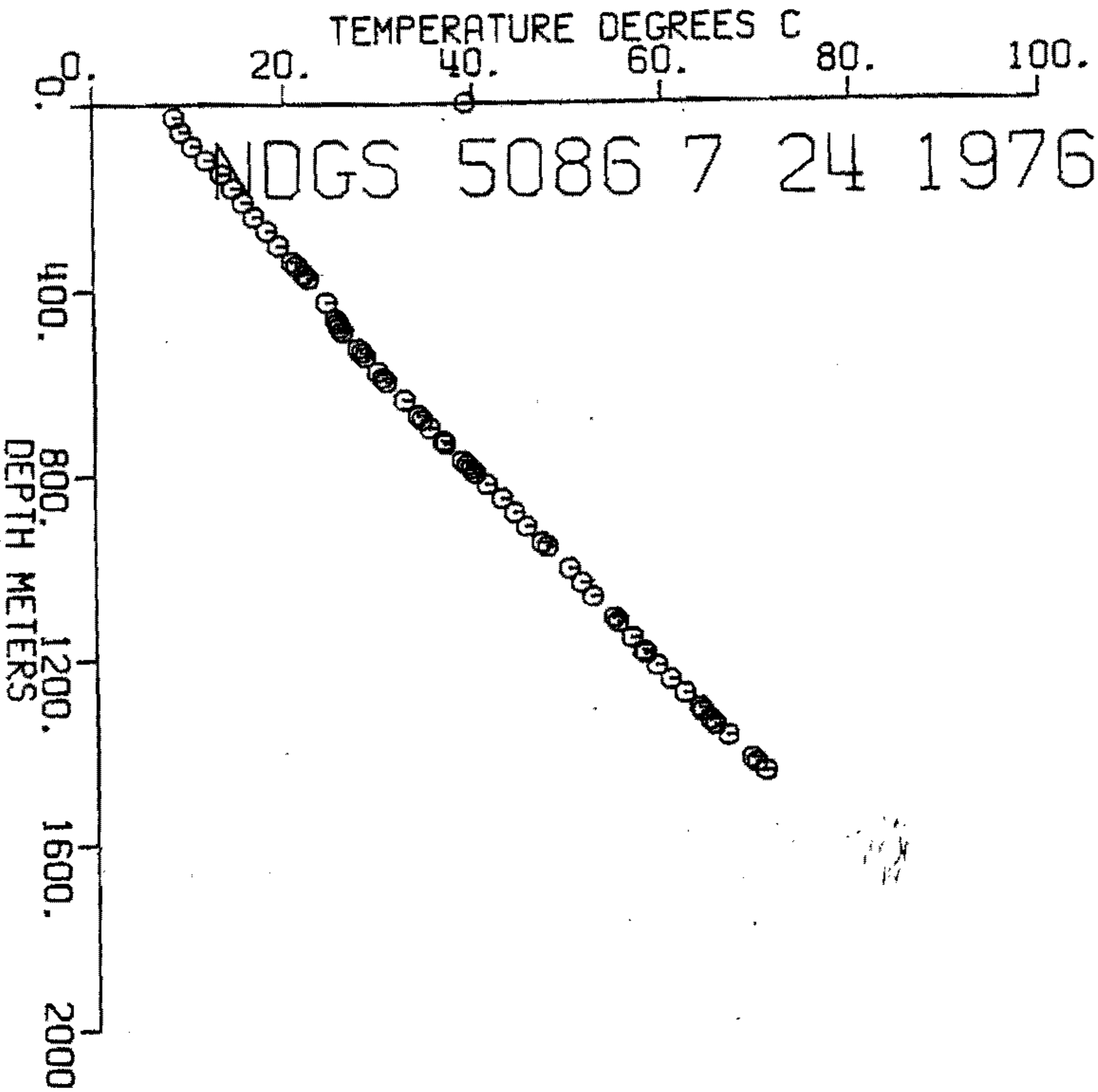
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
151.49	160.63	4.00	1.00	0.25
551.69	560.83	4.22	1.00	0.24
555.70	564.80	4.54	1.00	0.22
633.68	640.00	3.73	2.00	0.27
640.00	647.10	3.73	2.00	0.27
731.52	735.00	3.97	1.00	0.25
735.50	744.60	3.97	2.00	0.25
748.89	758.04	3.30	1.00	0.30
908.30	914.00	4.29	2.00	0.23
914.50	921.40	4.28	2.00	0.23
1053.70	1062.80	2.48	1.00	0.40
1104.59	1113.74	4.18	2.00	0.24
1114.00	1117.70	4.78	1.00	0.21
1181.70	1186.00	2.95	1.00	0.34
1187.00	1187.80	4.03	1.00	0.25
1306.70	1311.50	2.55	1.00	0.39
1312.00	1315.80	3.60	1.00	0.28
1416.40	1419.50	2.79	1.00	0.36
1443.80	1449.00	2.61	1.00	0.38

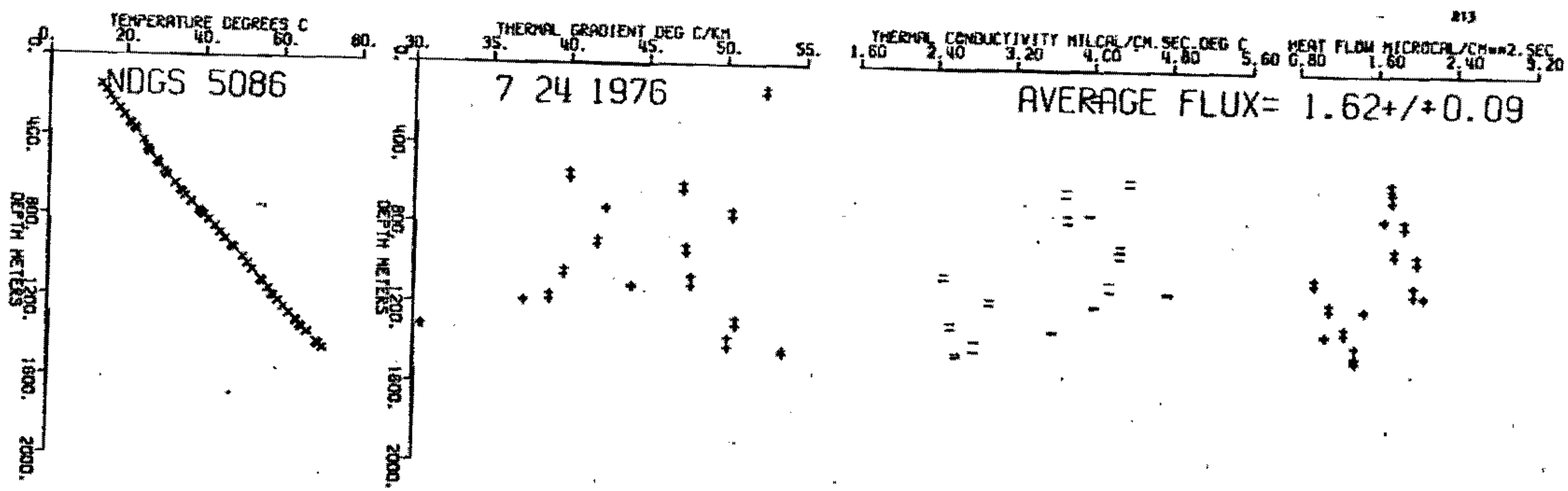
HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
121.92	152.40	4.00	52.46	2.10
546.14	579.15	4.38	40.01	1.75
601.07	640.14	3.73	47.26	1.76
729.26	735.30	3.97	42.35	1.68
735.30	772.12	3.75	50.45	1.89
884.32	914.46	4.29	41.85	1.80
914.46	948.96	4.28	47.54	2.03
1036.66	1066.86	2.48	39.69	0.98
1066.86	1113.89	4.18	47.84	2.00
1113.89	1122.76	4.78	44.07	2.11
1158.30	1186.86	2.95	38.76	1.14
1186.86	1192.99	4.03	37.10	1.50
1280.40	1311.95	2.55	50.66	1.29
1311.95	1321.19	3.60	30.51	1.10
1371.66	1421.80	2.79	50.16	1.40
1430.91	1449.26	2.61	53.61	1.40

AVERAGE HEAT FLUX= 1.62 +/- 0.09 H.F.U. STD DEV 0.370

METHOD #2 FLUX= 1.61 H.F.U. # OF CONDUCTIVITIES=25.0
UPPER DEPTH 121.92 LOWER DEPTH 1449.26 METERS


TEMPERATURE DEGREES C
0.
20.
40.
60.
80.
100.
NDGS 5086 7 24 1976
DEPTH METERS
0.
400.
800.
1200.
1600.
2000.


NDGS 5086
7 24 1976
AVERAGE FLUX= 1.62+/+0.09
TEMPERATURE DEGREES C
THERMAL GRADIENT DEG C/KM
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
DEPTH METERS
#13

NDGS 5086 BARNWELL STATE 1-16
MCKENZIE COUNTY 146N 103W SECTION 16 NE NE
47 28' 25" NORTH LATITUDE 103 47' 58" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=19.00 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
7 14 1975	7 3 1972	5 27 1972	6 29 1972

DRILLING PERIOD= 33 DAYS DAYS SINCE 1ST PERIOD= 1110
CASING SIZE 11.86CM ELEVATION 722.07 METERS ABOVE M.S.L.

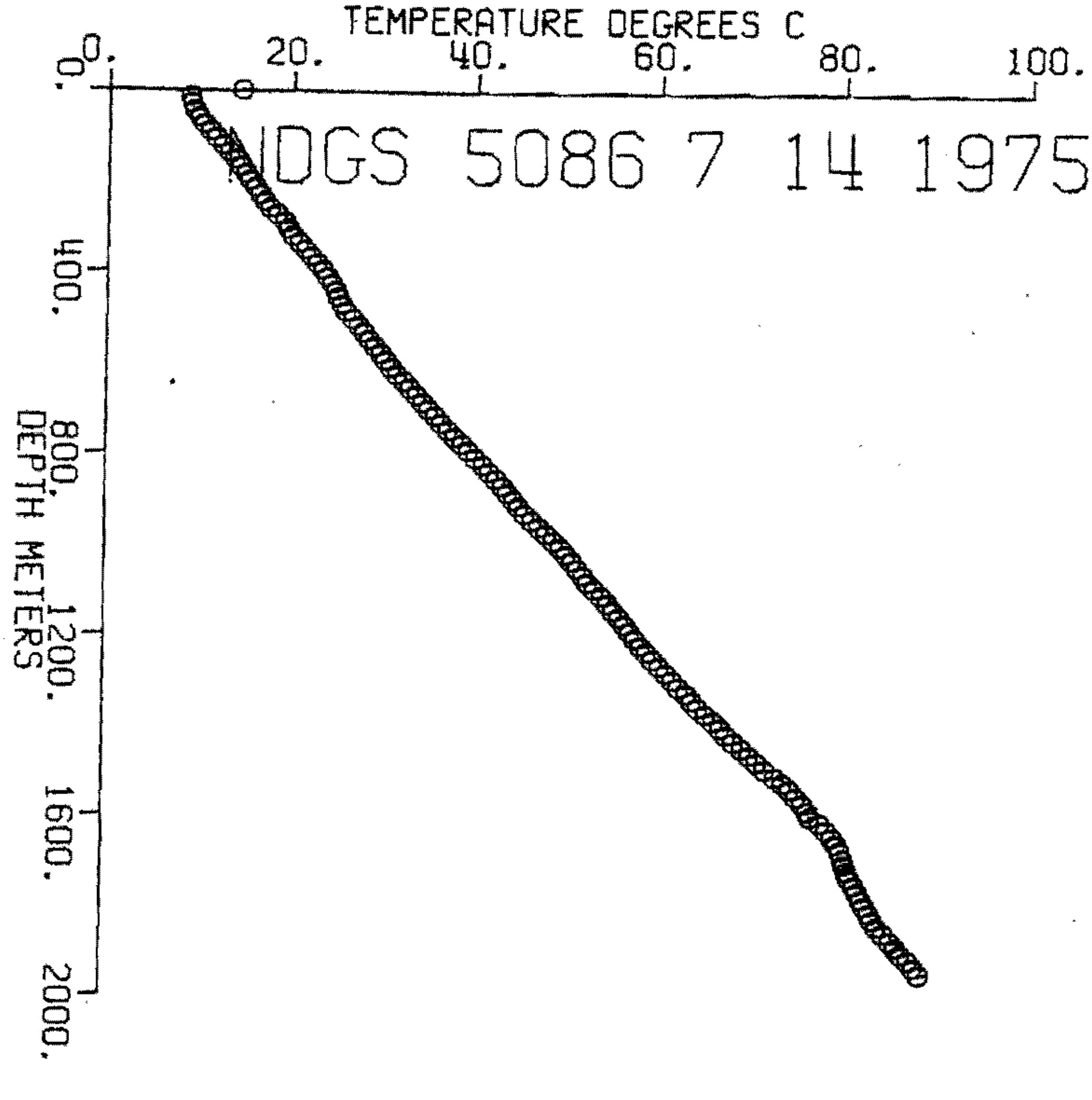
DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	13835.00	0.0	14.43	
				-370.55
50.00	17488.00	15.24	8.78	
				10.35
100.00	17370.00	30.48	8.94	
				25.13
150.30	17086.00	45.81	9.32	
				31.28
200.10	16743.00	60.99	9.80	
				37.21
250.00	16345.00	76.20	10.36	
				40.42
300.10	15924.00	91.47	10.98	
				47.19
350.00	15460.00	106.68	11.70	
				48.88
400.00	14995.00	121.92	12.44	
				41.64
450.00	14612.00	137.16	13.08	
				42.47
500.00	14233.00	152.40	13.72	
				40.55
550.00	13882.00	167.64	14.34	
				36.78
600.20	13571.00	182.94	14.90	
				29.57
650.70	13320.00	198.33	15.36	
				37.86
700.00	13014.00	213.36	15.93	
				36.59
750.00	12722.00	228.60	16.49	
				34.71
800.00	12452.00	243.84	17.01	
				35.81
850.10	12180.00	259.11	17.56	
				51.01
900.00	11806.00	274.32	18.34	
				52.59
953.20	11410.10	290.54	19.19	
				30.21
1000.00	11216.00	304.80	19.62	
				29.73
1050.00	11016.00	320.04	20.07	
				45.91
1100.00	10711.00	335.28	20.77	
				44.29
1150.00	10426.00	350.52	21.45	
				41.83
1200.00	10165.00	365.76	22.09	
				42.34
1253.20	9892.60	381.98	22.77	
				44.06
1300.10	9650.00	396.27	23.40	
				30.07
1350.10	9478.00	411.51	23.86	
				36.21

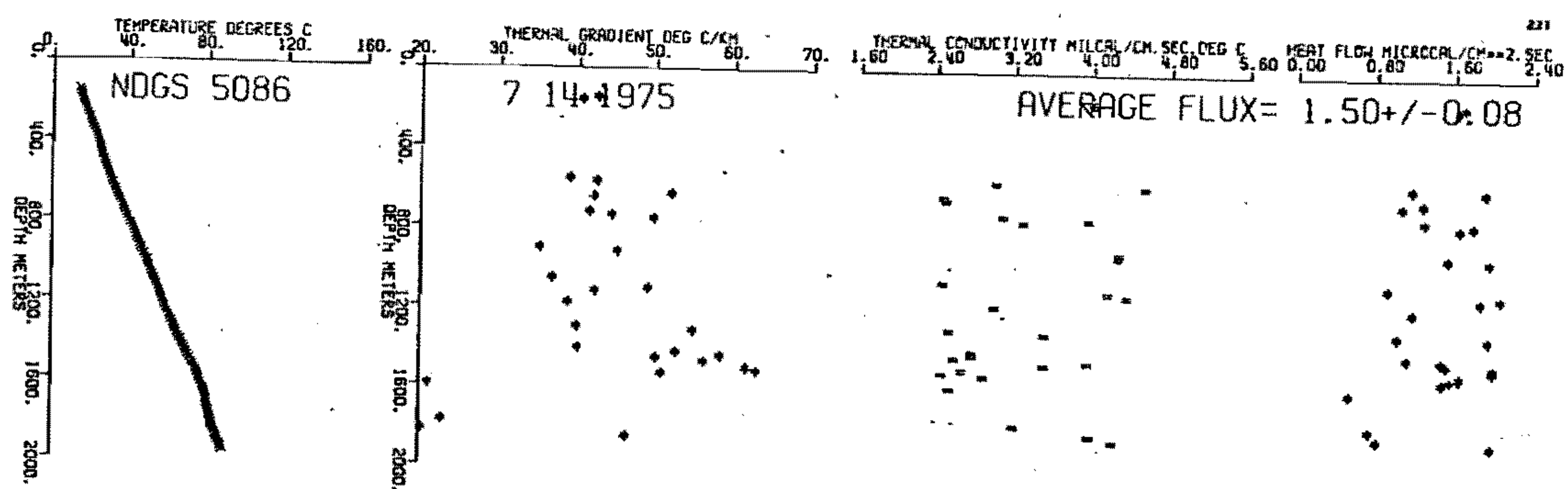
DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
1400.20	9275.00	426.78	24.41	27.52
1450.20	9124.60	442.02	24.83	18.54
1500.10	9025.00	457.23	25.12	24.86
1550.20	8893.00	472.50	25.49	29.84
1600.10	8738.00	487.71	25.95	44.51
1657.40	8480.00	505.18	26.73	43.53
1700.00	8298.00	518.16	27.29	39.12
1750.00	8111.00	533.40	27.89	39.31
1800.00	7928.00	548.64	28.49	39.11
1851.00	7745.00	564.18	29.09	42.52
1900.00	7559.00	579.12	29.73	35.09
1950.10	7406.00	594.39	30.27	38.25
2000.00	7244.00	609.60	30.85	43.05
2050.10	7066.00	624.87	31.50	52.14
2100.00	6858.00	640.08	32.30	43.13
2150.00	6691.00	655.32	32.95	47.90
2200.00	6511.00	670.56	33.68	43.52
2250.10	6352.00	685.83	34.35	42.69
2301.40	6197.00	701.47	35.02	48.72
2350.10	6034.00	716.31	35.74	42.60
2400.10	5892.50	731.55	36.39	45.52
2450.00	5746.00	746.76	37.08	50.88
2500.00	5587.00	762.00	37.86	50.69
2550.00	5433.80	777.24	38.63	46.46
2600.00	5298.00	792.48	39.34	54.22
2650.20	5144.00	807.78	40.17	53.90
2700.10	4997.00	822.99	40.99	43.68
2750.20	4881.00	838.26	41.65	49.97
2800.00	4753.00	853.44	42.41	43.62
2850.00	4644.00	868.68	43.08	40.64
2900.00	4545.20	883.92	43.70	42.42
2950.10	4444.40	899.19	44.34	36.36
3000.00	4360.00	914.40	44.90	46.29

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
3050.10	4254.70	929.67	45.60	
3100.10	4139.50	944.91	46.40	52.29
3150.30	4036.50	960.21	47.14	48.03
3200.00	3923.50	975.36	47.97	54.96
3250.70	3821.50	990.81	48.74	50.22
3300.10	3725.30	1005.87	49.50	50.01
3350.00	3646.70	1021.08	50.13	41.51
3400.00	3571.30	1036.32	50.75	40.75
3450.00	3499.40	1051.56	51.36	39.83
3500.00	3432.50	1066.80	51.93	37.93
3550.00	3366.90	1082.04	52.52	38.08
3600.00	3284.60	1097.28	53.26	49.02
3650.00	3202.50	1112.52	54.03	50.19
3700.20	3132.00	1127.82	54.69	43.40
3750.00	3067.00	1143.00	55.32	41.35
3800.30	3003.60	1158.33	55.95	40.96
3850.00	2944.00	1173.48	56.55	39.94
3900.00	2885.30	1188.72	57.16	39.99
3950.20	2834.40	1204.02	57.70	35.36
4001.00	2780.00	1219.50	58.29	38.17
4050.00	2720.00	1234.44	58.97	45.35
4100.00	2661.00	1249.68	59.66	44.94
4150.00	2599.40	1264.92	60.39	48.20
4200.00	2541.20	1280.16	61.10	46.81
4250.00	2484.90	1295.40	61.81	46.51
4300.00	2436.40	1310.64	62.44	41.09
4350.00	2372.00	1325.88	63.29	56.07
4400.00	2332.10	1341.12	63.84	35.66
4450.70	2279.60	1356.57	64.57	47.38
4500.00	2222.90	1371.60	65.38	54.17
4550.10	2164.90	1386.87	66.24	56.17
4600.10	2114.90	1402.11	67.00	49.98
4650.20	2074.60	1417.38	67.63	41.22
				54.01

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
4700.00	2023.50	1432.56	68.45	59.53
4750.10	1968.60	1447.83	69.36	51.27
4800.20	1922.20	1463.10	70.14	57.52
4850.00	1871.90	1478.28	71.02	55.30
4900.00	1824.80	1493.52	71.86	62.89
4959.50	1763.30	1511.66	73.00	64.22
5000.00	1722.00	1524.00	73.79	52.05
5050.20	1681.60	1539.30	74.59	45.94
5100.20	1647.00	1554.54	75.29	42.90
5150.00	1615.60	1569.72	75.94	32.62
5209.00	1587.90	1587.70	76.53	22.17
5250.40	1574.90	1600.32	76.81	68.01
5300.10	1528.10	1615.47	77.84	48.65
5350.00	1495.50	1630.68	78.58	40.29
5400.00	1469.10	1645.92	79.19	34.65
5450.00	1446.80	1661.16	79.72	25.31
5500.20	1430.70	1676.46	80.11	16.14
5561.00	1418.40	1694.99	80.40	12.55
5600.00	1412.30	1706.88	80.55	14.48
5650.30	1403.30	1722.21	80.78	25.32
5700.00	1387.90	1737.36	81.16	31.21
5750.00	1369.10	1752.60	81.64	27.10
5800.00	1353.00	1767.84	82.05	23.86
5850.50	1338.90	1783.23	82.42	25.31
5900.00	1324.40	1798.32	82.80	33.00
5950.00	1305.60	1813.56	83.30	21.36
6000.10	1293.60	1828.83	83.63	33.39
6050.40	1275.00	1844.16	84.14	47.57
6100.00	1249.40	1859.28	84.86	44.72
6157.30	1222.30	1876.74	85.64	44.83
6200.00	1202.60	1889.76	86.22	32.84
6250.40	1185.90	1905.12	86.73	56.84
6300.30	1157.90	1920.33	87.59	35.66

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
6350.00	1140.80	1935.48	88.13	
				39.94
6400.30	1121.80	1950.81	88.74	


TEMPERATURE DEGREES C
0.
20.
40.
60.
80.
100.
NDGS 5086 7 14 1975
0.
400.
800.
1200.
1600.
2000.
DEPTH METERS


NDGS 5086
7 14 1975
AVERAGE FLUX= 1.50+/-0.08
TEMPERATURE DEGREES C
0. 40. 80. 120. 160.
THERMAL GRADIENT DEG C/KM
20. 30. 40. 50. 60. 70.
THERMAL CONDUCTIVITY MILCAL/CM. SEC. DEG C
1.60 2.40 3.20 4.00 4.80 5.60
HEAT FLOW MICROCAL/CM**2. SEC
0.00 0.80 1.60 2.40
DEPTH METERS
0. 400. 800. 1200. 1600. 2000.

NDGS 5086 BARNWELL STATE 1-16
MCKENZIE COUNTY 146N 103W SECTION 16 NE NE
47 28' 25" NORTH LATITUDE 103 47' 58" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=14.35 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
7 13 1975	7 3 1972	5 27 1972	6 29 1972

DRILLING PERIOD= 33 DAYS DAYS SINCE 1ST PERIOD= 1109
CASING SIZE 11.86CM ELEVATION 722.07 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	17850.00	0.0	10.58	
				-209.06
30.00	19410.00	9.14	8.67	
				5.10
60.00	19370.00	18.29	8.71	
				30.41
90.00	19134.00	27.43	8.99	
				26.67
120.00	18930.00	36.58	9.24	
				29.50
150.00	18707.00	45.72	9.51	
				35.32
180.00	18444.00	54.86	9.83	
				39.84
210.00	18153.00	64.01	10.19	
				40.53
240.00	17862.00	73.15	10.56	
				44.80
270.00	17547.00	82.30	10.97	
				50.46
300.00	17207.00	91.44	11.43	
				54.49
330.00	16848.00	100.58	11.93	
				50.70
360.00	16522.00	109.73	12.40	
				38.58
390.00	16279.00	118.87	12.75	
				23.31
420.00	16134.00	128.02	12.96	
				43.15
450.00	15870.00	137.16	13.36	
				43.76
480.00	15607.00	146.30	13.76	
				40.21
510.00	15370.00	155.45	14.13	
				27.45
550.00	15157.00	167.64	14.46	
				31.38
600.00	14857.00	182.88	14.94	
				34.15
650.00	14538.00	198.12	15.46	
				41.06
700.00	14165.00	213.36	16.08	
				38.93
750.00	13822.00	228.60	16.68	
				35.53
800.00	13517.00	243.84	17.22	
				43.06
850.00	13158.00	259.08	17.88	
				53.57
900.00	12727.00	274.32	18.69	
				42.31
950.00	12398.00	289.56	19.34	
				26.66
1000.00	12196.00	304.80	19.74	
				38.18

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
1050.00	11913.00	320.04	20.32	
				49.77
1100.00	11555.00	335.28	21.08	
				41.49
1150.00	11266.00	350.52	21.72	
				43.83
1200.00	10970.00	365.76	22.38	
				42.77
1250.00	10690.00	381.00	23.04	
				38.18
1300.00	10447.00	396.24	23.62	
				34.97
1350.00	10230.00	411.48	24.15	
				10.12
1397.00	10172.00	425.81	24.29	

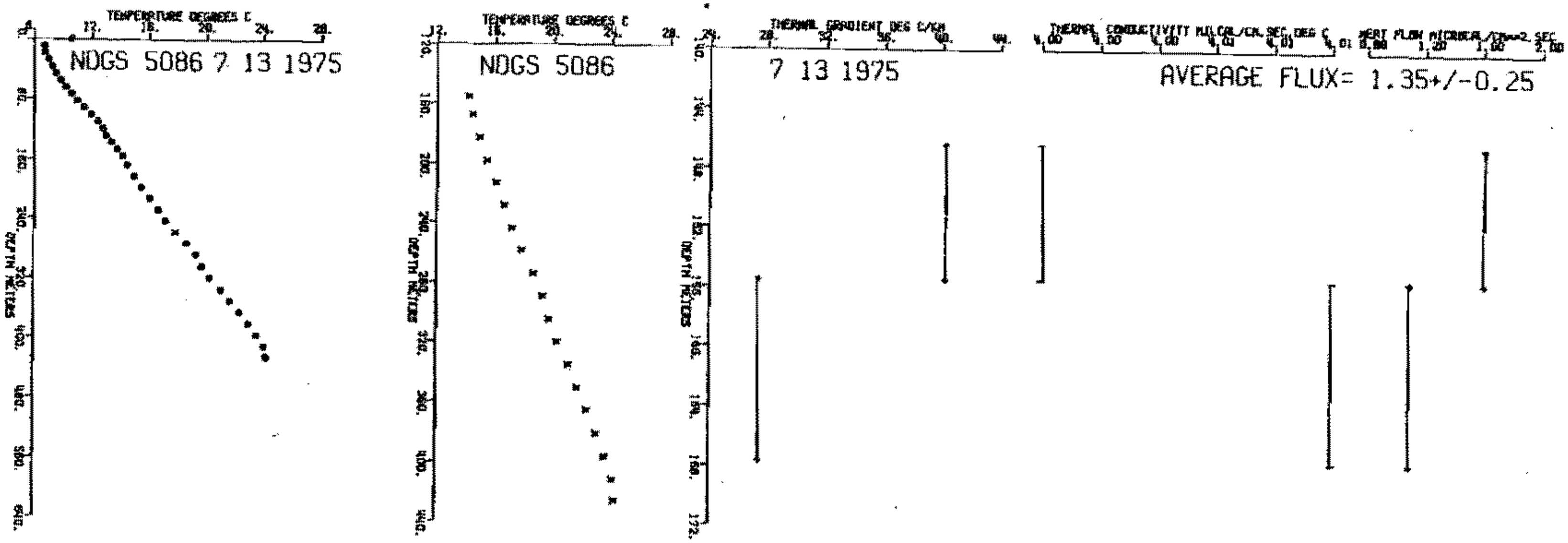
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
151.49	155.00	4.00	1.00	0.25
156.00	160.63	4.01	1.00	0.25

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
146.30	155.45	4.00	40.21	1.61
155.45	167.64	4.01	27.45	1.10

AVERAGE HEAT FLUX= 1.35 +/- 0.25 H.F.U. STD DEV 0.359

METHOD #2 FLUX= 1.32 H.F.U. # OF CONDUCTIVITIES= 2.0
UPPER DEPTH 146.30 LOWER DEPTH 167.64 METERS



NDGS 5086 7 13 1975
TEMPERATURE DEGREES C
DEPTH METERS
NDGS 5086
TEMPERATURE DEGREES C
DEPTH METERS
7 13 1975
THERMAL GRADIENT DEG C/KM
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM SEC DEG C
HEAT FLOW MICROCAL/CM**2 SEC
AVERAGE FLUX= 1.35+/-0.25

NDSWC 2615 USGS OBSERVATION WATER WELL
GRAND FORKS COUNTY 150N 50W SECTION 28 AAA
47 47' 16" NORTH LATITUDE 97 02' 47" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=17.30 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
9 15 1976	9 2 1966	9 1 1966	9 2 1966

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 3663
CASING SIZE 3.81CM ELEVATION 259.08 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	12509.00	0.0	19.12	
				-1657.24
25.00	21385.00	7.62	6.49	
				397.10
50.00	18700.00	15.24	9.51	
				16.02
75.00	18600.00	22.86	9.64	
				-31.98
100.00	18800.00	30.48	9.39	
				48.19
125.00	18500.00	38.10	9.76	
				-4.87
150.00	18530.00	45.72	9.72	
				29.25
175.00	18350.00	53.34	9.95	
				9.84
200.00	18290.00	60.96	10.02	
				3.59
223.00	18270.00	67.97	10.05	

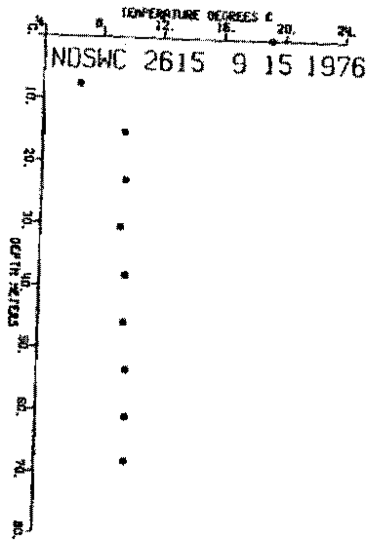
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
34.52	36.12	4.00	1.00	0.25
40.92	42.52	5.70	1.00	0.18
50.52	52.12	5.79	1.00	0.17
55.33	56.93	6.03	1.00	0.17
58.53	60.13	4.39	1.00	0.23

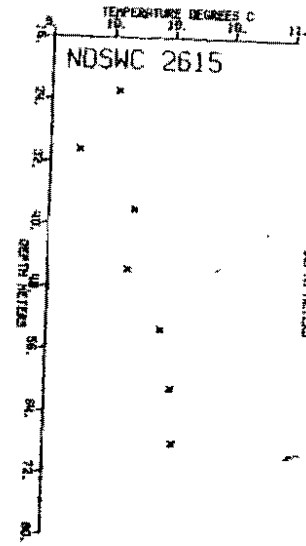
HEAT FLUX CALCULATION INTERVAL METHOD

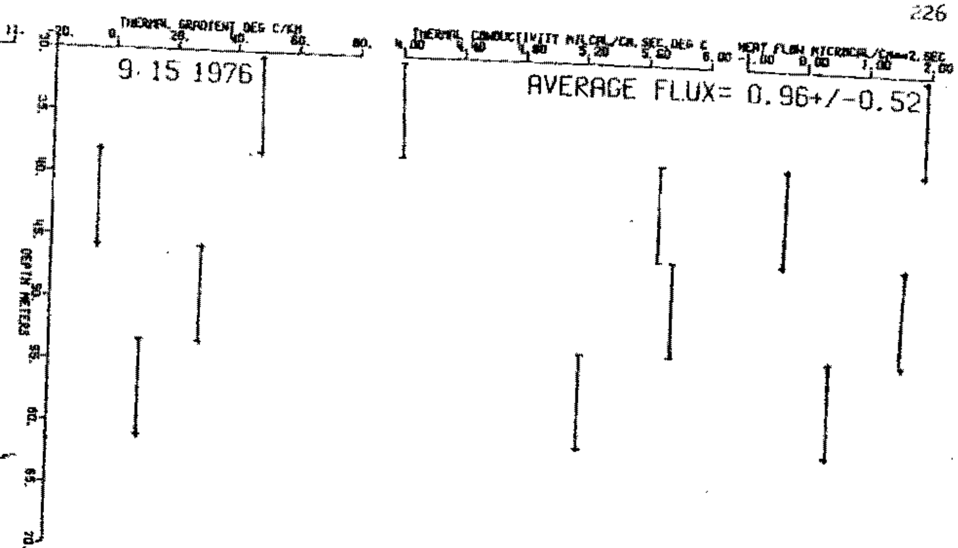
DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
30.48	38.10	4.00	48.19	1.93
38.10	45.72	5.70	-4.87	-0.28
45.72	53.34	5.79	29.25	1.69
53.34	60.96	5.21	9.84	0.51

AVERAGE HEAT FLUX= 0.96 +/- 0.52 H.F.U. STD DEV 1.034

METHOD #2 FLUX= 0.55 H.F.U. # OF CONDUCTIVITIES= 4.0
UPPER DEPTH 15.24 LOWER DEPTH 53.34 METERS


TEMPERATURE DEGREES C
NDSWC 2615 9 15 1976
DEPTH METERS


TEMPERATURE DEGREES C
NDSWC 2615
DEPTH METERS


THERMAL GRADIENT DEG C/KM
9.15 1976
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 0.96+/-0.52

NDSWC 2615 USGS OBSERVATION WATER WELL
GRAND FORKS COUNTY 150N 50W SECTION 28 AAA
47 47' 16" NORTH LATITUDE 97 02' 47" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=17.30 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
9 15 1976	9 2 1966	9 1 1966	9 2 1966

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 3663
CASING SIZE 3.81CM ELEVATION 259.08 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	12509.00	0.0	19.12	
				-1657.24
25.00	21385.00	7.62	6.49	
				397.10
50.00	18700.00	15.24	9.51	
				16.02
75.00	18600.00	22.86	9.64	
				8.11
125.00	18500.00	38.10	9.76	
				12.19
175.00	18350.00	53.34	9.95	
				9.84
200.00	18290.00	60.96	10.02	
				3.59
223.00	18270.00	67.97	10.05	

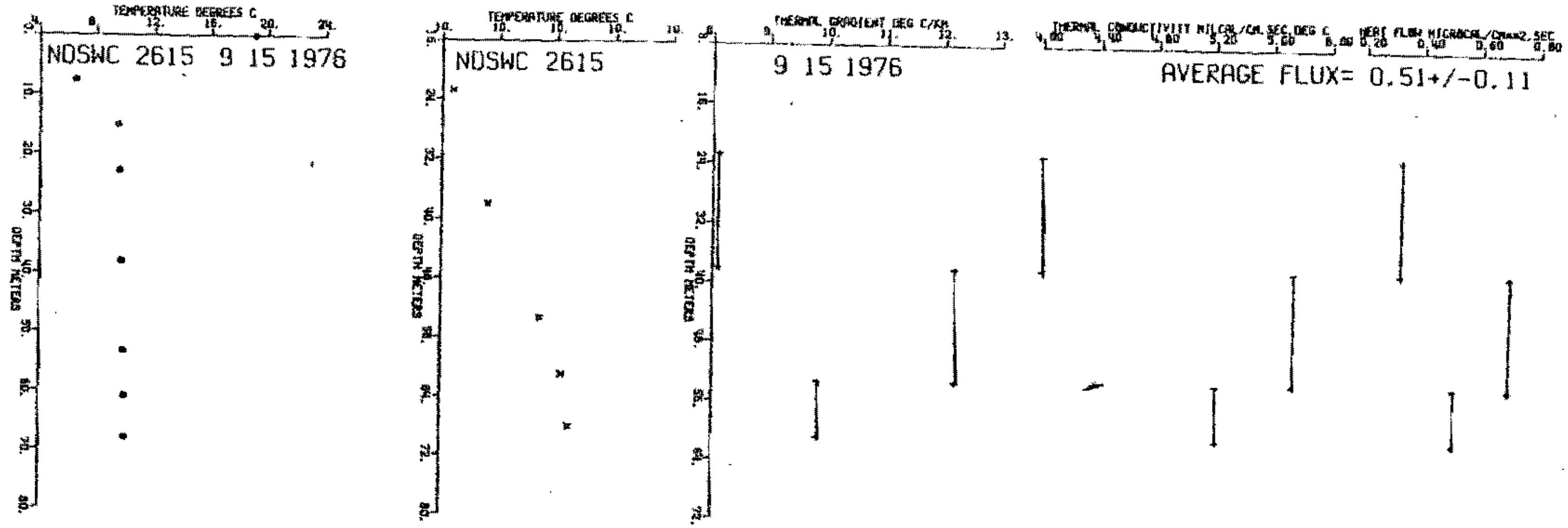
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
34.52	36.12	4.00	1.00	0.25
40.92	42.52	5.70	1.00	0.18
50.52	52.12	5.79	1.00	0.17
55.33	56.93	6.03	1.00	0.17
58.53	60.13	4.39	1.00	0.23

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
22.86	38.10	4.00	8.11	0.32
38.10	53.34	5.74	12.19	0.70
53.34	60.96	5.21	9.84	0.51

AVERAGE HEAT FLUX= 0.51 +/- 0.11 H.F.U. STD DEV 0.188

METHOD #2 FLUX= 0.55 H.F.U. # OF CONDUCTIVITIES= 4.0
UPPER DEPTH 15.24 LOWER DEPTH 53.34 METERS


TEMPERATURE DEGREES C
NDSWC 2615 9 15 1976
DEPTH METERS
TEMPERATURE DEGREES C
NDSWC 2615
DEPTH METERS
THERMAL GRADIENT DEG C/KM
9 15 1976
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 0.51+/-0.11

NDSWC 2430 USGS OBSERVATION WATER WELL
GRAND FORKS COUNTY 152N 50W SECTION 29 DDA
47 57' 5" NORTH LATITUDE 97 4' 0" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=20.05 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
9 15 1976	9 6 1965	9 5 1965	9 6 1965

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 4024
CASING SIZE 3.81CM ELEVATION 251.76 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
1.00	11510.00	0.30	21.18	
				-1916.19
25.00	20750.00	7.62	7.16	
				14.19
50.00	20650.00	15.24	7.27	
				1.44
75.00	20640.00	22.86	7.28	
				14.29
100.00	20540.00	30.48	7.39	
				11.50
125.00	20460.00	38.10	7.48	
				11.12
151.00	20380.00	46.02	7.57	
				16.65
175.00	20270.00	53.34	7.69	
				10.19
200.00	20200.00	60.96	7.77	
				36.77
210.00	20100.00	64.01	7.88	

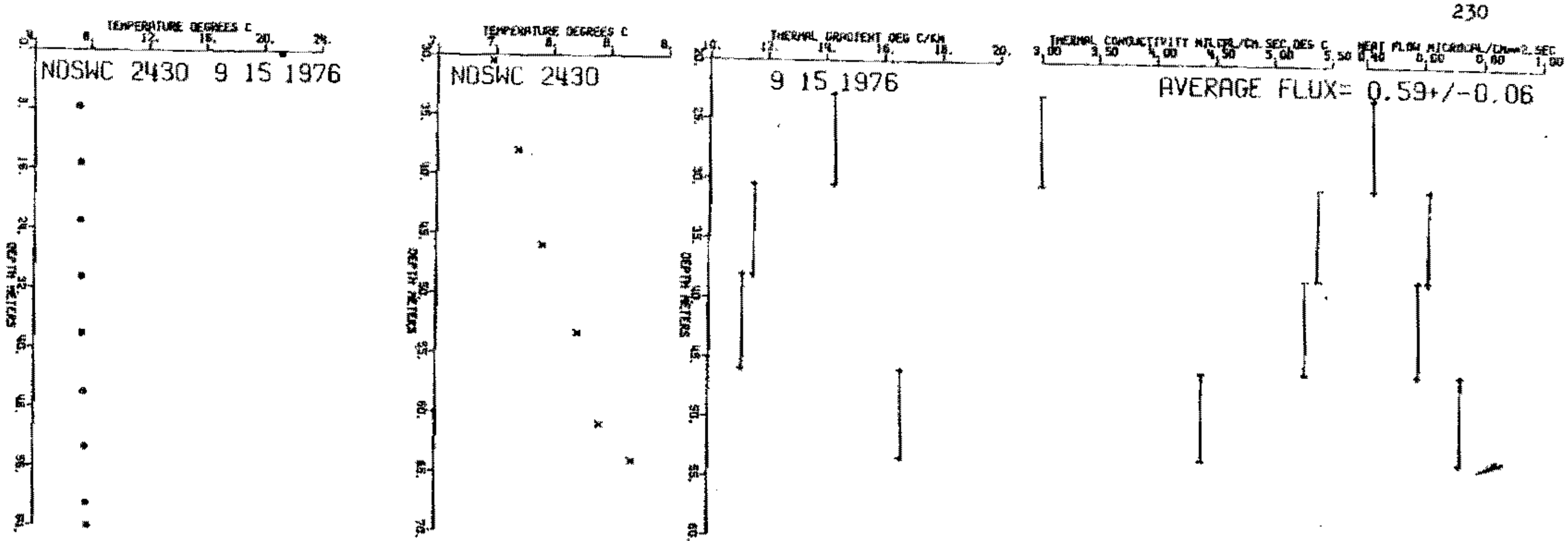
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
27.20	28.80	3.00	1.00	0.33
33.60	35.20	5.40	1.00	0.19
43.20	44.80	5.29	1.00	0.19
48.01	49.61	4.51	1.00	0.22
51.21	52.81	4.29	1.00	0.23

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
22.86	30.48	3.00	14.29	0.43
30.48	38.10	5.40	11.50	0.62
38.10	46.02	5.29	11.12	0.59
46.02	53.34	4.40	16.65	0.73

AVERAGE HEAT FLUX= 0.59 +/- 0.06 H.F.U. STD DEV 0.126

METHOD #2 FLUX= 0.57 H.F.U. # OF CONDUCTIVITIES= 5.0
UPPER DEPTH 22.86 LOWER DEPTH 53.34 METERS


TEMPERATURE DEGREES C
NOSWC 2430 9 15 1976
DEPTH METERS
TEMPERATURE DEGREES C
NOSWC 2430
DEPTH METERS
THERMAL GRADIENT DEG C/KM
9 15 1976
DEPTH METERS
THERMAL CONDUCTIVITY MILLICAL/CM. SEC DEG C
HEAT FLOW MICROCAL/CM**2. SEC
AVERAGE FLUX= 0.59+/-0.06

NDSWC 3830 USGS OBSERVATION WATER WELL
PEMBINA COUNTY 160N 54W SECTION 31 CCC
48 37' 50" NORTH LATITUDE 97 39' 51" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=16.20 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
8 6 1975	9 2 1969	9 1 1969	9 2 1969

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 2163
CASING SIZE 3.81CM ELEVATION 278.28 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	14900.00	0.0	14.87	
				-994.29
30.00	22080.00	9.14	5.78	
				-174.94
60.00	23740.00	18.29	4.18	
				236.88
90.00	21525.00	27.43	6.34	
				25.63
120.00	21300.00	36.58	6.58	
				31.77
150.00	21025.00	45.72	6.87	
				8.73
180.00	20950.00	54.86	6.95	
				20.56
210.00	20775.00	64.01	7.14	
				17.17
240.00	20630.00	73.15	7.29	
				24.51
270.00	20425.00	82.30	7.52	
				9.05
300.00	20350.00	91.44	7.60	
				3.04
330.00	20325.00	100.58	7.63	
				242.97
342.00	19540.00	104.24	8.52	

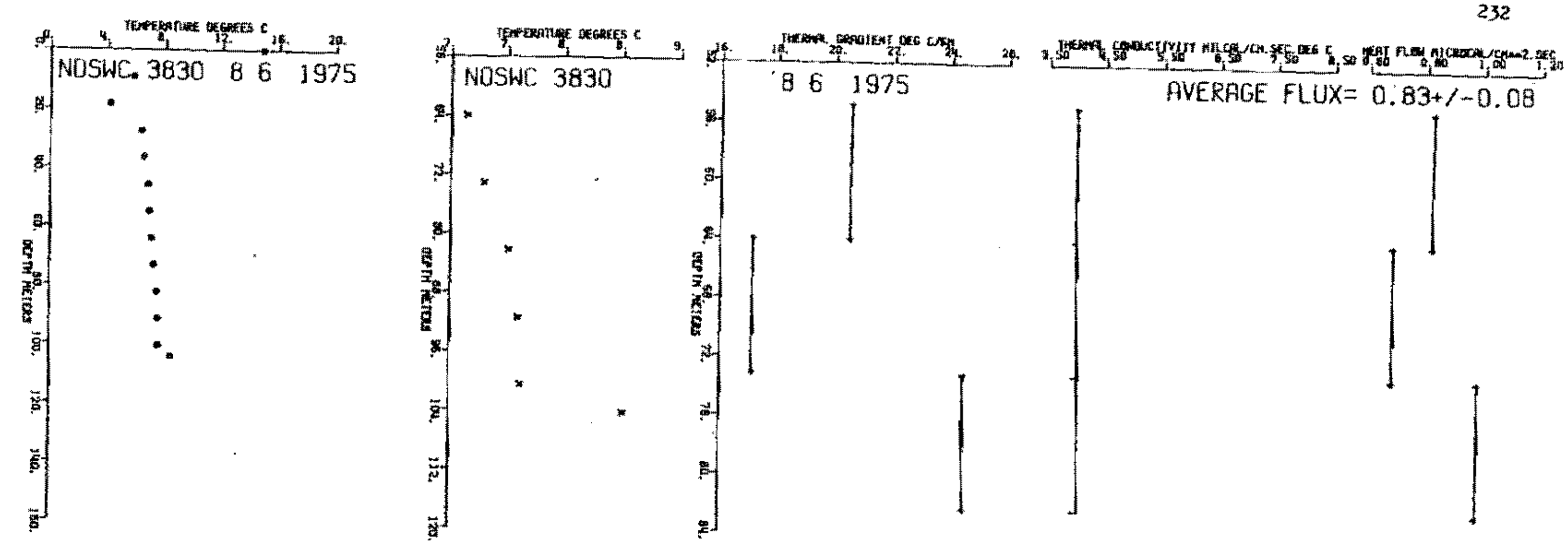
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
55.00	63.70	4.00	1.00	0.25
65.00	72.84	4.00	1.00	0.25
73.45	81.99	4.00	1.00	0.25

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
54.86	64.01	4.00	20.56	0.82
64.01	73.15	4.00	17.17	0.69
73.15	82.30	4.00	24.51	0.98

AVERAGE HEAT FLUX= 0.83 +/- 0.08 H.F.U. STD DEV 0.147

METHOD #2 FLUX= 0.83 H.F.U. # OF CONDUCTIVITIES= 3.0
UPPER DEPTH 54.86 LOWER DEPTH 82.30 METERS


TEMPERATURE DEGREES C
NDSWC 3830 8 6 1975
DEPTH METERS
TEMPERATURE DEGREES C
NDSWC 3830
DEPTH METERS
THERMAL GRADIENT DEG C/KM
8 6 1975
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 0.83+/-0.08

NDSWC 3830 USGS OBSERVATION WATER WELL
PEMBINA COUNTY 160N 54W SECTION 31 CCC
48 37' 50" NORTH LATITUDE 97 39' 51" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=16.23 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
2 21 1976	9 2 1969	9 1 1969	9 2 1969

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 2362
CASING SIZE 3.81CM ELEVATION 278.28 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	37586.00	0.0	-5.36	
				1261.29
30.00	21690.00	9.14	6.17	
				4.49
60.00	21650.00	18.29	6.21	
				68.62
90.00	21050.00	27.43	6.84	
				22.19
120.00	20860.00	36.58	7.04	
				42.69
150.00	20500.00	45.72	7.43	
				10.84
180.00	20410.00	54.86	7.53	
				12.04
210.00	20310.00	64.01	7.64	
				50.28
240.00	19900.00	73.15	8.10	
				16.18
270.00	19770.00	82.30	8.25	
				57.00
300.00	19320.00	91.44	8.77	

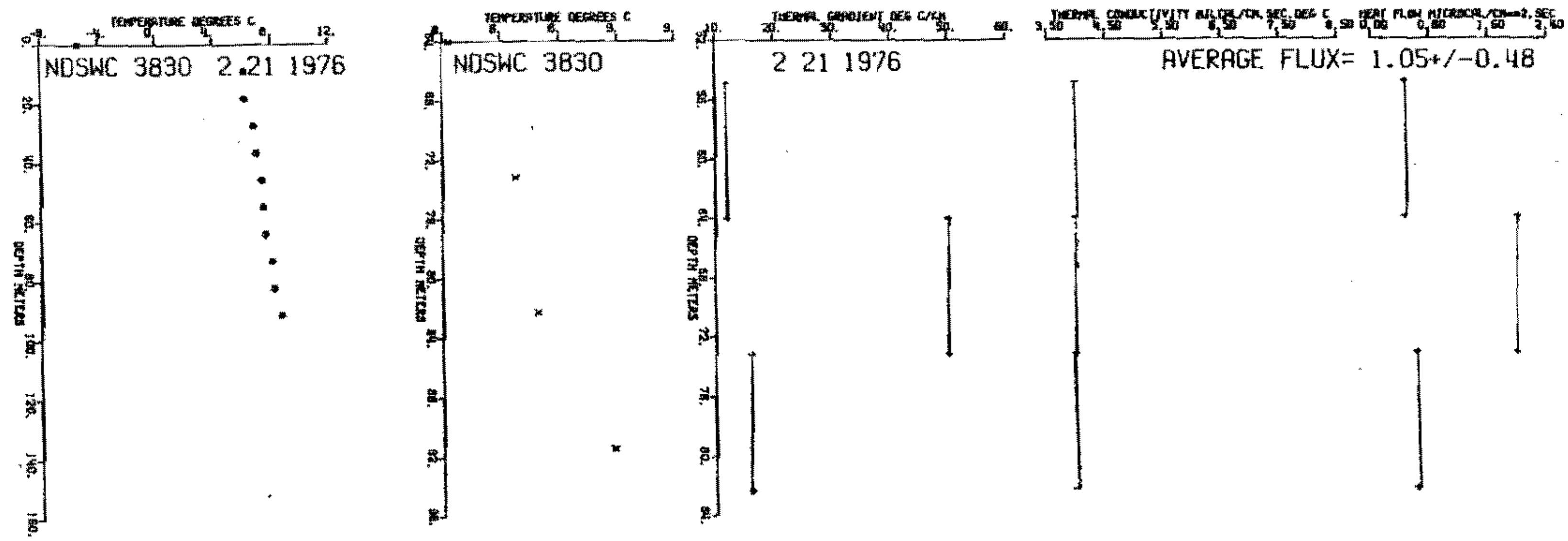
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
55.00	63.70	4.00	1.00	0.25
65.00	72.84	4.00	1.00	0.25
73.45	81.99	4.00	1.00	0.25

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
54.86	64.01	4.00	12.04	0.48
64.01	73.15	4.00	50.28	2.01
73.15	82.30	4.00	16.18	0.65

AVERAGE HEAT FLUX= 1.05 +/- 0.48 H.F.U. STD DEV 0.839

METHOD #2 FLUX= 1.05 H.F.U. # OF CONDUCTIVITIES= 3.0
UPPER DEPTH 54.86 LOWER DEPTH 82.30 METERS


TEMPERATURE DEGREES C
NDSWC 3830 2.21 1976
DEPTH METERS
TEMPERATURE DEGREES C
NDSWC 3830
DEPTH METERS
THERMAL GRADIENT DEG C/KM
2 21 1976
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.05+/-0.48

NDSWC 3825 USGS OBSERVATION WATER WELL
PEMBINA COUNTY 160N 56W SECTION 16 AAA4
48 41' 14" NORTH LATITUDE 97 51' 46" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=18.00 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
7 1 1975	7 3 1969	7 2 1969	7 3 1969

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 2188
CASING SIZE 5.08CM ELEVATION 314.55 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	12235.00	0.0	19.66	
				-1193.60
30.00	19340.00	9.14	8.75	
				-168.55
60.00	20708.00	18.29	7.21	
				-24.03
90.00	20912.00	27.43	6.99	
				9.85
120.00	20828.00	36.58	7.08	
				23.92
150.00	20626.00	45.72	7.30	
				27.77
180.00	20394.00	54.86	7.55	
				44.21
210.00	20031.00	64.01	7.96	
				46.16
240.00	19660.00	73.15	8.38	
				48.49
270.00	19279.00	82.30	8.82	
				42.24
300.00	18954.00	91.44	9.21	
				-1941.00
330.00	44000.00	100.58	-8.54	
				2020.01
360.00	18363.00	109.73	9.93	
				12.82
390.00	18269.00	118.87	10.05	
				24.80
414.00	18125.00	126.19	10.23	

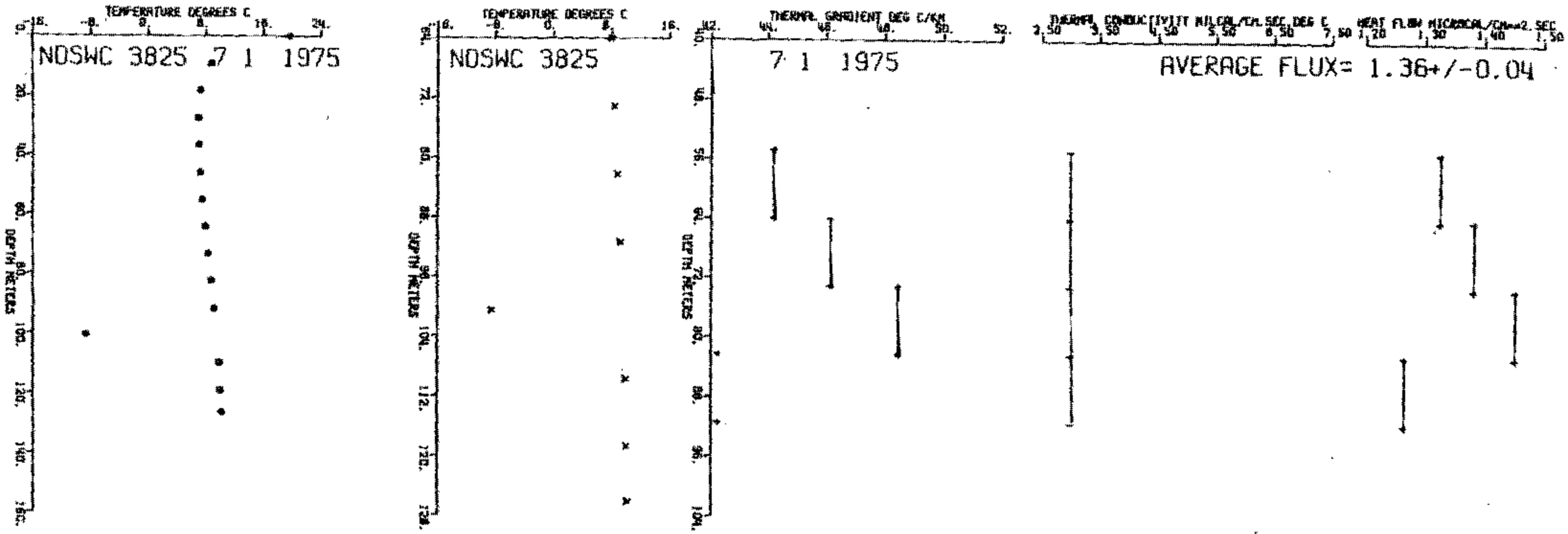
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
55.17	63.70	3.00	1.00	0.33
64.31	72.85	3.00	1.00	0.33
73.46	72.85	3.00	1.00	0.33
82.60	91.13	3.00	1.00	0.33

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
54.86	64.01	3.00	44.21	1.33
64.01	73.15	3.00	46.16	1.38
73.15	82.30	3.00	48.49	1.45
82.30	91.44	3.00	42.24	1.27

AVERAGE HEAT FLUX= 1.36 +/- 0.04 H.F.U. STD DEV 0.080

METHOD #2 FLUX= 1.36 H.F.U. # OF CONDUCTIVITIES= 4.0
UPPER DEPTH 54.86 LOWER DEPTH 91.44 METERS


TEMPERATURE DEGREES C
NOSWC 3825 7 1 1975
DEPTH METERS
TEMPERATURE DEGREES C
NOSWC 3825
DEPTH METERS
THERMAL GRADIENT DEG C/KM
7 1 1975
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 1.36+/-0.04

NDSWC 3842 USGS OBSERVATION WATER WELL
PEMBINA COUNTY 161N 55W SECTION 15 BCD-1
48 46' 07" NORTH LATITUDE 97 44' 55" WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=21.22 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
7 1 1975	10 2 1969	10 1 1969	10 2 1969

DRILLING PERIOD= 1 DAYS DAYS SINCE 1ST PERIOD= 2097
CASING SIZE 5.08CM ELEVATION 307.24 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
0.0	12050.00	0.0	20.04	
				-969.97
30.00	17400.00	9.14	11.17	
				-365.33
60.00	20142.00	18.29	7.83	
				-22.27
90.00	20325.00	27.43	7.63	
				-12.09
120.00	20425.00	36.58	7.52	
				13.19
150.00	20316.00	45.72	7.64	
				5.58
180.00	20270.00	54.86	7.69	
				7.29
210.00	20210.00	64.01	7.76	
				24.51
240.00	20010.00	73.15	7.98	
				13.59
270.00	19900.00	82.30	8.10	
				7.48
300.00	19840.00	91.44	8.17	
				5.73
313.00	19820.00	95.40	8.19	

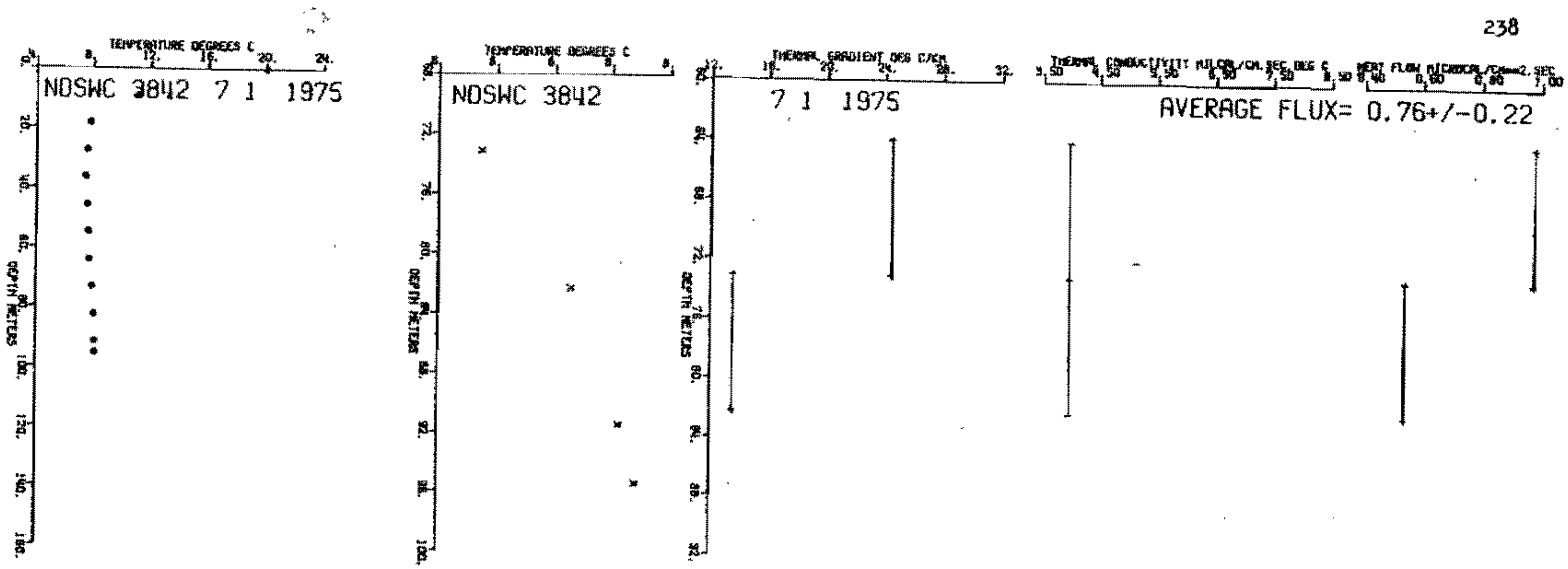
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
64.31	72.85	4.00	1.00	0.25
73.46	81.99	4.00	1.00	0.25

HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
64.01	73.15	4.00	24.51	0.98
73.15	82.30	4.00	13.59	0.54

AVERAGE HEAT FLUX= 0.76 +/- 0.22 H.F.U. STD DEV 0.309

METHOD #2 FLUX= 0.98 H.F.U. # OF CONDUCTIVITIES= 2.0
UPPER DEPTH 64.01 LOWER DEPTH 73.15 METERS


NDSWC 3842 7 1 1975
TEMPERATURE DEGREES C
DEPTH METERS
NDSWC 3842
TEMPERATURE DEGREES C
DEPTH METERS
7 1 1975
THERMAL GRADIENT DEG C/KM
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
AVERAGE FLUX= 0.76+/-0.22

NDGS 3479 /1280 CARRIE HOVLAND #1 COMBS TEMPERATURES
BURKE COUNTY 163N 91W SECTION 23 SE SE
48 55' 18'' NORTH LATITUDE 102 26' 0'' WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=15.00 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
9 13 1964	1 15 1957	10 21 1956	1 10 1957

DRILLING PERIOD= 81 DAYS DAYS SINCE 1ST PERIOD= 2801
CASING SIZE 15.24CM ELEVATION 592.53 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
213.25	15694.90	65.00	11.33	
				-25.77
311.68	16210.00	95.00	10.56	
				1.38
426.51	16177.00	130.00	10.61	
				21.16
524.93	15753.10	160.00	11.24	
				31.67
623.36	15150.10	190.00	12.19	
				10.65
721.78	14953.20	220.00	12.51	
				22.01
820.21	14556.20	250.00	13.17	
				31.66
918.64	14006.40	280.00	14.12	
				23.67
1017.06	13611.30	310.00	14.83	
				38.04
1115.49	12991.00	340.00	15.97	
				29.30
1213.91	12535.20	370.00	16.85	
				31.66
1312.34	12063.50	400.00	17.80	
				39.33
1410.76	11506.00	430.00	18.98	
				40.66
1509.19	10960.20	460.00	20.20	
				35.00
1607.61	10508.90	490.00	21.25	
				41.00
1706.04	10007.60	520.00	22.48	
				33.33
1804.46	9620.70	550.00	23.48	
				38.33
1902.89	9197.10	580.00	24.63	
				38.45
2001.31	8794.00	610.00	25.78	
				35.11
2099.74	8444.00	640.00	26.84	
				39.13
2198.16	8073.00	670.00	28.01	
				32.31
2296.59	7779.20	700.00	28.98	
				39.62
2395.01	7433.40	730.00	30.17	
				126.04
2493.44	6447.00	760.00	33.95	
				52.37
2591.86	6082.80	790.00	35.52	
				48.30
2690.29	5769.30	820.00	36.97	
				50.97
2723.10	5663.70	830.00	37.48	
				54.11
2739.50	5608.60	835.00	37.75	
				57.84

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
2755.91	5550.30	840.00	38.04	
				48.01
2772.31	5502.50	845.00	38.28	
				49.30
2854.33	5265.10	870.00	39.51	
				58.13
2870.74	5210.90	875.00	39.80	
				43.42
2887.14	5170.90	880.00	40.02	
				59.98
2903.54	5116.20	885.00	40.32	
				55.61
2985.56	4871.40	910.00	41.71	
				52.32
3083.99	4611.40	940.00	43.28	
				60.99
3182.42	4328.00	970.00	45.11	
				58.07
3198.82	4284.80	975.00	45.40	
				56.02
3215.22	4243.50	980.00	45.68	
				57.94
3231.63	4201.30	985.00	45.97	
				51.34
3280.84	4091.60	1000.00	46.74	
				56.12
3297.24	4052.50	1005.00	47.02	
				70.00
3313.65	4004.30	1010.00	47.37	
				53.92
3330.05	3967.60	1015.00	47.64	
				57.63
3444.88	3705.20	1050.00	49.66	
				74.13
3510.50	3524.90	1070.00	51.14	
				72.09
3526.90	3482.70	1075.00	51.50	
				63.99
3543.31	3445.70	1080.00	51.82	
				55.97
3559.71	3413.70	1085.00	52.10	
				49.34
3658.14	3250.30	1115.00	53.58	
				56.02
3674.54	3220.40	1120.00	53.86	
				47.10
3690.95	3195.10	1125.00	54.10	
				54.55
3707.35	3166.00	1130.00	54.37	
				59.15
3723.75	3134.80	1135.00	54.66	
				54.86
3740.16	3106.20	1140.00	54.94	
				53.39
3838.58	2945.10	1170.00	56.54	
				33.48
3904.20	2880.70	1190.00	57.21	
				28.08
3920.60	2867.40	1195.00	57.35	
				29.97
3937.01	2853.30	1200.00	57.50	
				23.98
4035.43	2786.70	1230.00	58.22	
				20.06
4051.84	2777.60	1235.00	58.32	
				23.29

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
4084.65	2756.70	1245.00	58.55	
				22.42
4101.05	2746.80	1250.00	58.66	
				21.33
4199.48	2691.00	1280.00	59.30	
				35.78
4297.90	2600.40	1310.00	60.38	
				38.25
4396.33	2507.50	1340.00	61.53	
				51.53
4494.75	2388.50	1370.00	63.07	
				51.13
4593.18	2277.00	1400.00	64.61	
				43.45
4691.60	2187.10	1430.00	65.91	
				33.30
4790.03	2121.00	1460.00	66.91	
				33.59
4888.45	2056.70	1490.00	67.92	
				30.08
4986.88	2001.10	1520.00	68.82	
				23.07
5085.30	1959.70	1550.00	69.51	
				23.72
5101.71	1952.60	1555.00	69.63	
				21.04
5167.32	1927.70	1575.00	70.05	
				26.21
5183.73	1920.00	1580.00	70.18	
				24.98
5282.15	1876.80	1610.00	70.93	
				24.70
5380.58	1835.20	1640.00	71.67	
				22.96
5479.00	1797.50	1670.00	72.36	
				19.97
5495.41	1792.10	1675.00	72.46	
				24.17
5511.81	1785.60	1680.00	72.58	
				28.07
5528.22	1778.10	1685.00	72.72	
				23.97
5643.05	1734.00	1720.00	73.56	
				24.95
5741.47	1695.70	1750.00	74.31	
				20.34
5839.89	1665.20	1780.00	74.92	
				30.58
5905.51	1635.30	1800.00	75.53	

NDGS 3479 /1280 CARRIE HOVLAND #1 COMBS TEMPERATURES

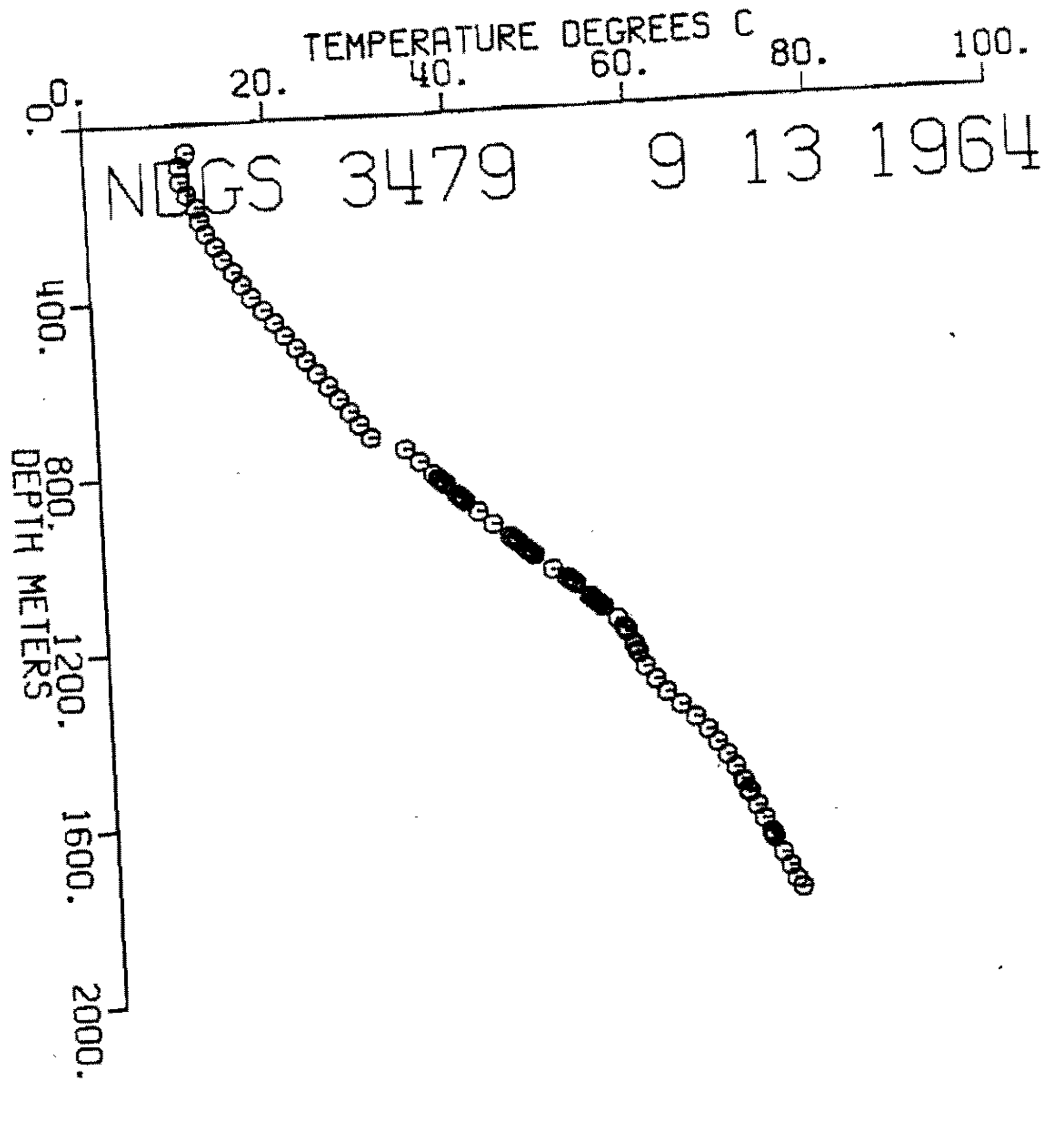
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
832.10	834.90	3.49	1.00	0.29
835.10	839.90	3.53	1.00	0.28
840.10	844.00	3.50	1.00	0.29
870.50	874.80	4.30	1.00	0.23
880.50	883.92	4.28	1.00	0.23
972.31	979.90	2.19	1.00	0.46
975.50	979.90	2.19	1.00	0.46
981.46	984.90	2.19	1.00	0.46
1000.50	1004.90	3.68	1.00	0.27
1005.50	1009.90	3.68	1.00	0.27
1010.50	1014.90	3.68	1.00	0.27
1072.90	1074.90	3.44	1.00	0.29
1075.50	1079.90	3.44	1.00	0.29
1080.10	1082.04	3.44	1.00	0.29
1117.62	1119.90	3.50	1.00	0.29
1120.10	1124.90	3.48	1.00	0.29
1125.10	1129.90	3.28	1.00	0.30
1130.10	1134.90	3.89	1.00	0.26
1135.90	1139.90	3.93	1.00	0.25
1190.10	1194.90	4.06	1.00	0.25
1195.10	1199.90	4.06	1.00	0.25
1230.10	1234.90	4.48	1.00	0.22
1246.63	1249.68	5.34	1.00	0.19
1551.43	1554.48	3.56	1.00	0.28
1575.82	1578.86	3.94	1.00	0.25
1673.35	1674.90	4.85	1.00	0.21
1675.10	1679.45	4.85	1.00	0.21
1680.10	1682.50	4.31	1.00	0.23

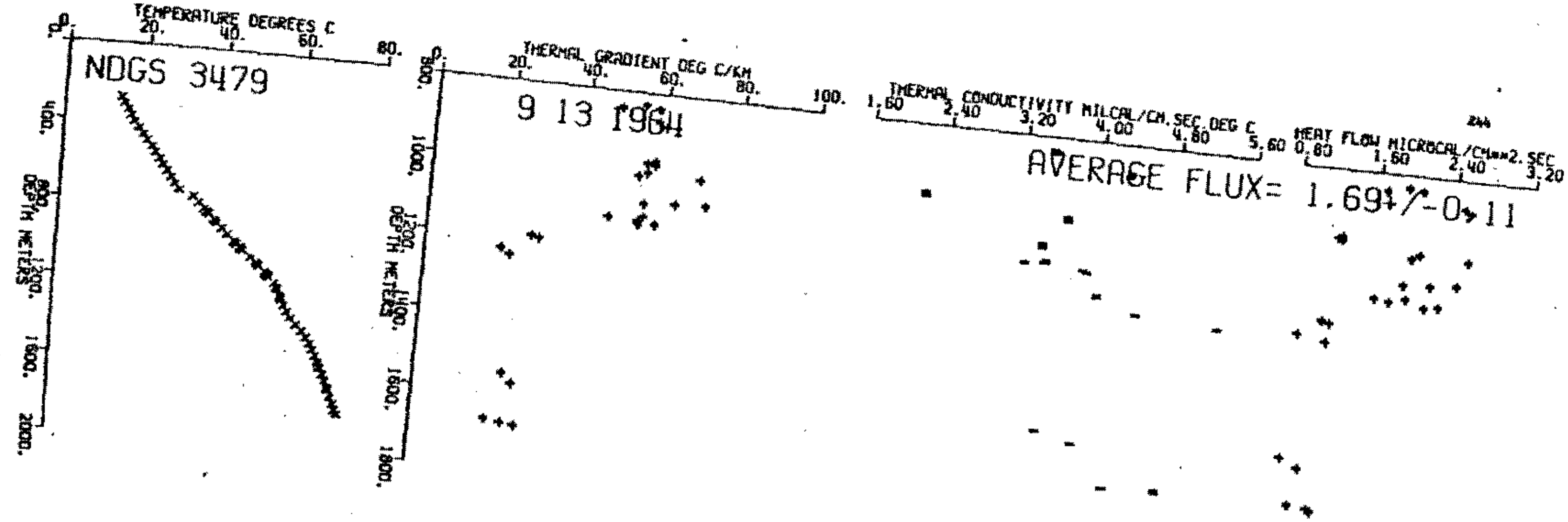
HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
830.00	835.00	3.49	54.11	1.89
835.00	840.00	3.53	57.84	2.04
840.00	845.00	3.50	48.01	1.68
870.00	875.00	4.30	58.13	2.50
880.00	885.00	4.28	59.98	2.57
970.00	975.00	2.19	58.07	1.27
975.00	980.00	2.19	56.02	1.23
980.00	985.00	2.19	57.94	1.27
1000.00	1005.00	3.68	56.12	2.07
1005.00	1010.00	3.68	70.00	2.58
1010.00	1015.00	3.68	53.92	1.99
1070.00	1075.00	3.44	72.09	2.48
1075.00	1080.00	3.44	63.99	2.20
1080.00	1085.00	3.44	55.97	1.93
1115.00	1120.00	3.50	56.02	1.96
1120.00	1125.00	3.48	47.10	1.64
1125.00	1130.00	3.28	54.55	1.79
1130.00	1135.00	3.89	59.15	2.30
1135.00	1140.00	3.93	54.86	2.16
1190.00	1195.00	4.06	28.08	1.14
1195.00	1200.00	4.06	29.97	1.22
1230.00	1235.00	4.48	20.06	0.90
1245.00	1250.00	5.34	22.42	1.20
1550.00	1555.00	3.56	23.72	0.84
1575.00	1580.00	3.94	26.21	1.03
1670.00	1675.00	4.85	19.97	0.97
1675.00	1680.00	4.85	24.17	1.17
1680.00	1685.00	4.31	28.07	1.21

AVERAGE HEAT FLUX= 1.69 +/- 0.11 H.F.U. STD DEV 0.557

METHOD #2 FLUX= 1.48 H.F.U. # OF CONDUCTIVITIES=28.0
UPPER DEPTH 250.00 LOWER DEPTH 1685.00 METERS


TEMPERATURE DEGREES C
0.
20.
40.
60.
80.
100.
NDGS 3479 9 13 1964
0.
400.
800.
1200.
1600.
2000.
DEPTH METERS


NDGS 3479
TEMPERATURE DEGREES C
DEPTH METERS
9 13 1964
THERMAL GRADIENT DEG C/KM
DEPTH METERS
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
HEAT FLOW MICROCAL/CM**2.SEC
244
AVERAGE FLUX= 1.69+/-0.11

NDGS 3342 / 2491 NELSON # 1 COMBS TEMPERATURES
BOTTINEAU COUNTY 163N 78W SECTION 19 NW NE
48 56' 6'' NORTH LATITUDE 100 40' 6'' WEST LONGITUDE
UNIVERSAL TIME OF TEMPERATURE LOG=16.00 HOURS.MINUTES

DATE LOGGED	DATE WELL COMPLETED	DATE SPUDDED	DATE OF DRILLING TERMINATION
9 12 1964	11 14 1959	10 21 1956	1 10 1957

DRILLING PERIOD= 81 DAYS DAYS SINCE 1ST PERIOD= 2800
CASING SIZE 17.78CM ELEVATION 460.25 METERS ABOVE M.S.L.

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
164.04	16305.00	50.00	10.42	
				11.49
262.47	16068.60	80.00	10.76	
				17.20
360.89	15727.30	110.00	11.28	
				8.00
459.32	15572.60	140.00	11.52	
				46.01
557.74	14717.10	170.00	12.90	
				30.66
656.17	14177.40	200.00	13.82	
				40.00
754.59	13506.40	230.00	15.02	
				42.00
853.02	12828.70	260.00	16.28	
				47.02
951.44	12117.00	290.00	17.69	
				44.94
984.25	11899.70	300.00	18.14	
				56.04
1000.66	11766.70	305.00	18.42	
				46.06
1017.06	11658.80	310.00	18.65	
				47.93
1033.47	11547.50	315.00	18.89	
				40.05
1049.87	11455.70	320.00	19.09	
				50.01
1066.27	11342.10	325.00	19.34	
				57.71
1181.10	10462.90	360.00	21.36	
				56.00
1230.32	10119.30	375.00	22.20	
				65.98
1246.72	9987.90	380.00	22.53	
				48.51
1377.95	9254.70	420.00	24.47	
				49.98
1394.36	9164.90	425.00	24.72	
				51.97
1410.76	9072.60	430.00	24.98	
				52.85
1459.97	8797.80	445.00	25.77	
				46.61
1476.38	8718.80	450.00	26.01	
				61.54
1492.78	8616.00	455.00	26.31	
				66.60
1574.80	8083.00	480.00	27.98	
				53.59
1591.21	8000.90	485.00	28.25	
				62.71
1607.61	7905.90	490.00	28.56	
				47.00
1706.04	7489.80	520.00	29.97	
				67.13

DEPTH FEET	RESISTANCE OHMS	DEPTH METERS	TEMPERATURE DEGREES C	THERMAL GRADIENT DEGREES C/KM
1820.87	6852.30	555.00	32.32	
1837.27	6772.90	560.00	32.63	62.08
1853.68	6687.10	565.00	32.97	68.04
1870.08	6634.80	570.00	33.18	41.95
1886.48	6573.10	575.00	33.43	50.06
1968.50	6272.30	600.00	34.69	50.41
2034.12	6033.90	620.00	35.74	52.50
2050.53	5996.50	625.00	35.91	33.92
2066.93	5976.80	630.00	36.00	18.02
2148.95	5853.90	655.00	36.57	22.78
2165.35	5832.60	660.00	36.67	20.02
2181.76	5805.10	665.00	36.80	26.02
2296.59	5624.90	700.00	37.67	24.85
2395.01	5404.50	730.00	38.78	37.01
2444.23	5274.40	745.00	39.46	45.50
2460.63	5222.00	750.00	39.74	56.17
2477.03	5177.50	755.00	39.98	48.21
2493.44	5139.80	760.00	40.19	41.15
2509.84	5099.90	765.00	40.41	43.96
2624.67	4840.70	800.00	41.89	42.30
2723.10	4679.30	830.00	42.86	32.31
2739.50	4651.70	835.00	43.03	33.99
2755.91	4621.00	840.00	43.22	38.07
2772.31	4598.60	845.00	43.36	27.89
2788.71	4573.10	850.00	43.52	32.09
2887.14	4465.10	880.00	44.21	23.00
2985.56	4393.20	910.00	44.68	15.63
3083.99	4298.10	940.00	45.31	21.05

NDGS 3342 / 2491 NELSON # 1 COMBS TEMPERATURES

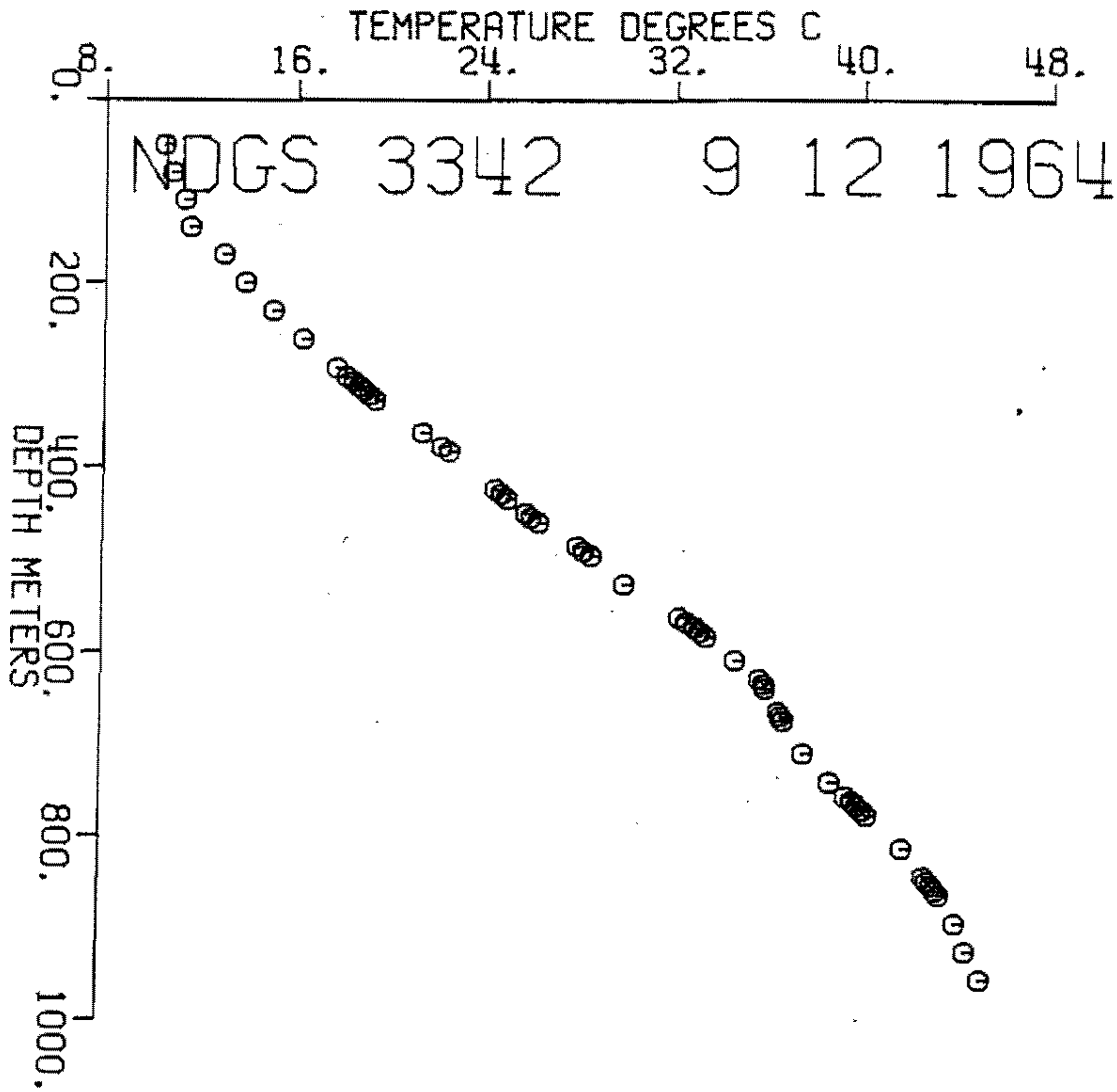
DEPTH INTERVAL METERS		THERMAL CONDUCTIVITY	NUMBER IN INTERVAL	THERMAL RESISTIVITY
301.45	304.90	3.15	1.00	0.32
305.10	309.10	3.15	1.00	0.32
318.74	319.90	3.39	1.00	0.29
320.10	324.74	3.39	1.00	0.29
372.00	375.90	4.01	1.00	0.25
375.10	379.60	4.01	1.00	0.25
420.32	424.90	3.11	1.00	0.32
425.10	429.00	3.11	1.00	0.32
169.16	170.68	4.84	2.00	0.21
447.75	449.90	4.51	1.00	0.22
450.10	452.75	4.51	1.00	0.22
482.00	484.90	2.58	1.00	0.39
485.10	489.33	2.58	1.00	0.39
557.48	559.90	4.52	1.00	0.22
560.10	564.90	4.52	1.00	0.22
565.10	569.62	3.63	1.00	0.28
570.10	572.00	2.73	1.00	0.37
621.49	624.90	3.42	1.00	0.29
624.90	628.00	3.42	1.00	0.29
658.06	659.90	5.30	1.00	0.19
660.10	664.90	5.30	1.00	0.19
746.46	749.90	3.72	1.00	0.27
750.10	754.90	3.99	1.00	0.25
755.10	759.90	4.21	1.00	0.24
760.10	763.60	4.21	1.00	0.24
831.80	834.90	3.77	1.00	0.27
835.10	837.00	3.77	1.00	0.27
843.99	844.80	4.11	1.00	0.24

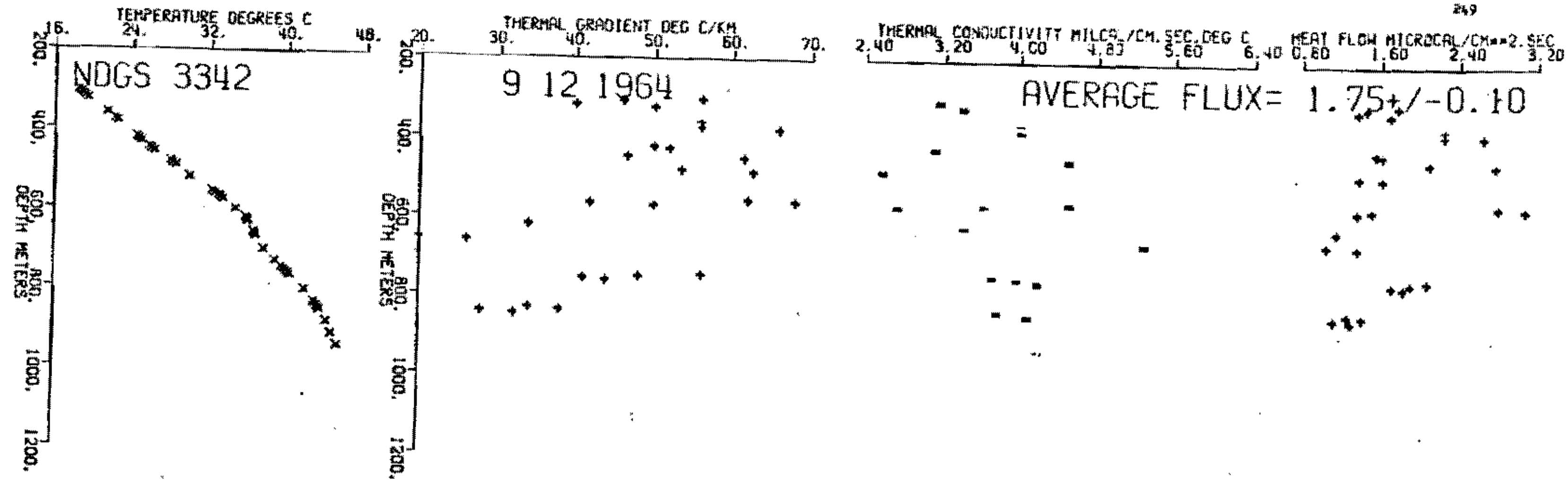
HEAT FLUX CALCULATION INTERVAL METHOD

DEPTH INTERVAL METERS		AVERAGE CONDUCTIVITY	THERMAL GRADIENT	HEAT FLUX MICROCAL /CM**2/SEC
300.00	305.00	3.15	56.04	1.77
305.00	310.00	3.15	46.06	1.45
315.00	320.00	3.39	40.05	1.36
320.00	325.00	3.39	50.01	1.70
360.00	375.00	4.01	56.00	2.25
375.00	380.00	4.01	65.98	2.65
420.00	425.00	3.11	49.98	1.55
425.00	430.00	4.26	51.97	2.22
445.00	450.00	4.51	46.61	2.10
450.00	455.00	4.51	61.54	2.78
480.00	485.00	2.58	53.59	1.38
485.00	490.00	2.58	62.71	1.62
555.00	560.00	4.52	62.09	2.81
560.00	565.00	4.52	68.04	3.08
565.00	570.00	3.63	41.95	1.52
570.00	575.00	2.73	50.06	1.37
620.00	625.00	3.42	33.92	1.16
655.00	660.00	5.30	20.02	1.06
660.00	665.00	5.30	26.02	1.38
745.00	750.00	3.72	56.17	2.09
750.00	755.00	3.99	48.21	1.92
755.00	760.00	4.21	41.15	1.73
760.00	765.00	4.21	43.96	1.85
830.00	835.00	3.77	33.99	1.28
835.00	840.00	3.77	38.07	1.44
840.00	845.00	4.11	27.89	1.15

AVERAGE HEAT FLUX= 1.79 +/- 0.11 H.F.U. STD DEV 0.555

METHOD #2 FLUX= 1.68 H.F.U. # OF CONDUCTIVITIES=27.0
UPPER DEPTH 300.00 LOWER DEPTH 850.00 METERS


TEMPERATURE DEGREES C
8.
16.
24.
32.
40.
48.
NDGS 3342 9 12 1964
0.
200.
400.
600.
800.
1000.
DEPTH METERS


NDGS 3342
TEMPERATURE DEGREES C
16. 24. 32. 40. 48.
DEPTH METERS
200. 400. 600. 800. 1000. 1200.
9 12 1964
THERMAL GRADIENT DEG C/KM
20. 30. 40. 50. 60. 70.
THERMAL CONDUCTIVITY MILCAL/CM.SEC.DEG C
2.40 3.20 4.00 4.80 5.60 6.40
HEAT FLOW MICROCAL/CM**2.SEC
0.80 1.60 2.40 3.20
AVERAGE FLUX= 1.75+/-0.10

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

16 August 1974

Seismic Discrimination Group
42 Carleton Street
Cambridge
Massachusetts 02142

Area Code 617
253-7851

Mr. Richard Scattolini
North Dakota Geological Survey
University Station
Grand Forks, North Dakota 58201

Dear Mr. Scattolini,

Mr. Delbert S. Leach, of the Environmental Data Service, has forwarded your request concerning Seismicity of North Dakota to me.

I have searched the literature of the U. S. Coast and Geodetic survey from 1928 to present without finding any reported epicenters within the state of North Dakota.

LASA, as you know, was not originally set up to work with near regional or regional data but the operators of LASA have been publishing a regional bulletin since January 1973. After scanning this bulletin, I have found 4 events that may be of interest to you.

1) March 7, 1974 15:51:09.1 Lat 48.6N Long 104.0W
   No m_b computed Montana - North Dakota Border
2) March 7, 1974 18:28:25.3 Lat 48.3N Long 103.1W
   No m_b computed Northwestern North Dakota
3) March 8, 1974 15:05:10.1 Lat 47.1N Long 106.3W
   m_b 2.4 Eastern Montana
4) March 8, 1974 15:06:49.7 Lat 47.1N Long 106.3W
   m_b 2.6 Eastern Montana

15 August 1974

Mr. R. Scattolini

Page 2

I cannot confirm the accuracy of these locations but the LASA operators believe them to be within .3 degrees of the source.

Let me know if we can be of any further assistance. You might also wish to contact the operators of LASA for assistance their address is:

Mr. Robert Matkins area code 406-245-6332
Philco-Ford Corp.
LASA Data Center
214 N 30th Street
Billings, Montana 59101

Sincerely yours,

Russell Needham

Russell Needham

RN:sks

cc: Mr. Delbert S. Leach

APPENDIX B

DETAILS OF HEAT PRODUCTION CALCULATIONS

Data on Heat Production Samples from the
University of North Dakota

Sample Number	N.D.G.S. Well Number	County	North Dakota Location				Depth of Sample (feet)	Rock Type
			¼ of ¼ Sec.	Section	Twp.	Range		
HP-1	1231	Williams	NE SE	2	155N	96W	13608	Orthopyroxene Granulite
HP-2	2219	Bottineau	SW SE	6	161N	79W	7284	Andesine Hornblende Schist
HP-3	20	Ramsey	NE NE	29	158N	62W	3220	Granite
HP-4	27	Cavalier	NW NW	28	159W	63W	3400	Altered Horn-blende Gneiss
HP-5	27	Cavalier	NW NW	28	159W	63W	3406	Hornblende Gneiss
HP-6	16	Emmons	SE SW	35	133N	75W	5360	Biotite Hornblende Gneiss
HP-7	16	Emmons	SE SW	35	133N	75W	5359	Biotite Hornblende Gneiss
HP-8	29	Grand Forks	SW SW	35	152N	51W	1801 to 2048	Granite
HP-9	-	Pembina	NE	8	160N	54W	1307	Banded Iron Formation
HP-10	3268	Billings	SW NE	10	139N	101W	13550 to 13750	Biotite Granodiorite

Heat Production Data

Sample	Well #	Radium (PPM)	Thorium (PPM)	Potassium (Percent)	Thorium/ Radium	Radium/ Potassium	Thorium/ Potassium
HP-1	A 123	2.10	9.90	6.93	4.71	0.30	1.43
HP-2	A2219	1.05	1.83	0.84	1.74	1.25	2.18
HP-3	A 20	3.75	27.87	4.35	7.43	0.86	6.41
HP-4	A 27	0.47	2.93	3.00	6.23	0.16	0.98
HP-5	A 27	0.34	1.55	1.42	4.56	0.24	1.09
HP-6	A 16	0.79	4.79	1.89	6.06	0.42	2.53
HP-7	A 16	2.01	7.97	4.48	3.97	0.45	1.78
HP-8	A 29	1.20	1.22	1.38	1.02	0.87	0.88
HP-9	A PC	0.65	2.63	1.00	4.05	0.65	2.63
HP-10	A3268	1.10	19.22	3.54	17.47	0.31	5.43

Heat Production Data

Well #	HMU µcal/ gm yr	Average HMU	HGU+ 10^{-13}cal/ cm^3 sec	Core Density gm/cc	Crushed Density gm/cc
A 123	5.38	5.38	1.71	2.49	2.85
A2219	1.36	1.36	0.43	2.70	2.91
A 20	9.49	9.49	3.01	2.52	2.54
A 27	1.74	1.34	0.42	2.39	2.36
A 27	0.94			2.62	2.42
A 16	2.05	3.16	1.00	2.70	2.40
A 16	4.27			2.87	2.68
A 29	1.49	1.49	0.47	---	2.23
A PC	1.27	1.27	0.40	3.11	2.95
A3268	5.60	5.60	1.78	---	2.44

NOTE: PRECISION OF RAEU & THU ANALYSES IS 0.05 PPM + 2 PCT OF STATED VALUE. PRECISION OF K ANALYSES IS 0.03 PCT + 1 PCT OF STATED VALUE. ALTHOUGH MORE DIGITS MAY BE SHOWN, ONLY FIRST 3 ARE SIGNIFICANT. WHEN TH/RAEU RATIO IS LESS THAN 1, TH ERROR MAY EXCEED NORMAL PRECISION, WHEN TH/RAEU RATIO EXCEEDS 15, RAEU ERROR MAY EXCEED NORMAL PRECISION. N. D. INDICATES THAT RADIOELEMENT WAS NOT DETERMINED BECAUSE PHOTOPEAKS WERE MASKED BY THOSE OF ANOTHER RADIOELEMENT WITH MUCH GREATER CONCENTRATION. THIS DOES NOT APPLY TO WELL A 3628 WHOSE ERROR IS LARGER BUT NOT DEFINED. 3/21/75

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